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Agent Reasoning Transparency: The Influence of Information Level on Automation-Induced Complacency

by Julia L Wright, Jessie YC Chen, Michael J Barnes, and Peter A Hancock

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14. ABSTRACT

To understand how the information available to an operator and the transparency of an intelligent agent's reasoning interact to affect complacent behavior, 2 between-subjects experiments were conducted. Participants supervised a 3-vehicle convoy as it traversed a simulated environment and rerouted the convoy when needed with the assistance of an intelligent agent. In Experiment 1 (low information), participants received information about their current route only; in Experiment 2 (high information), they received information about both their current route and the suggested alternate route. In Experiment 1, access to agent reasoning was found to be an effective deterrent to complacent behavior. However, the addition of information that created ambiguity for the operator encouraged complacency, resulting in reduced performance and poorer trust calibration. In Experiment 2, access to agent reasoning was found to have little effect on complacent behavior, and there were notable differences due to individual differences. These findings suggest that when the operator has more information regarding their task environment, individual difference factors may influence performance outcomes more than access to agent reasoning. These findings indicate some negative outcomes resulting from the incongruous transparency of agent reasoning may be mitigated by increasing the information available to the operator.

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Executive Summary

This research examined how the information available to the operator in a human–robot team and the transparency of an intelligent agent's reasoning affected complacent behavior in a route-selection task in a simulated environment. In 2 between-subjects experiments, participants supervised a 3-vehicle convoy as it traversed a simulated environment and rerouted the convoy when needed with the assistance of an intelligent agent. Participants received information regarding potential events along their route; in Experiment 1 (low information setting) they received information about their current route only; in Experiment 2 (high information setting) they received information about both their current route and the suggested alternate route.

In Experiment 1, access to agent reasoning was found to be an effective deterrent to complacent behavior. However, the addition of information that created ambiguity for the operator encouraged complacency, resulting in reduced performance and poorer trust calibration. These findings align with studies that have shown ambiguous information can encourage complacency; as such, caution should be exercised when considering how transparent to make agent reasoning and what information should be included. In Experiment 2, access to agent reasoning was found to have little effect on complacent behavior. However, the addition of information that created ambiguity for the operator appeared to encourage complacency, as indicated by reduced performance and shorter decision times. Unlike the first experiment, there were notable differences in complacent behavior, performance, operator trust, and situation awareness due to individual difference factors. As such, these findings suggest that when the operator has more information regarding their task environment, access to agent reasoning may be beneficial; however, individual difference factors will greatly influence performance outcomes.

The amount of information the operator has regarding the task environment has a profound effect on the proper use of the agent. These findings indicate some negative outcomes resulting from the incongruous transparency of agent reasoning may be mitigated by increasing the information the operator has regarding the task environment.

1. Introduction

Human–agent teaming is an essential component to the future of the next generation of defense, as outlined in the US Department of Defense's Third Offset Strategy (DoDLive 2015). Autonomous technology is rapidly becoming part of our everyday lives, and humans find themselves increasingly reliant on their autonomous partners for support in a variety of tasks and settings (Chen and Barnes 2014). In military applications, successful collaboration within these teams will determine whether the teaming results in a decided advantage in the field or is a potentially dangerous pairing of incompatible entities. Key to the successful collaboration between the human and the autonomous agent is communication; specifically, as the degree of autonomy of the agent increases, it becomes more difficult for the human to understand the reasoning behind the agent's actions (Chen and Barnes 2014; Kim and Hinds 2006). Increased transparency of the agent's reasoning has been proposed to bridge this gap in understanding (Chen et al. 2014).

The present research investigated how the transparency of agent reasoning, within the context of human–agent teaming, influences operator performance and behavior in a dynamic, multitasking environment. The effect of access to agent reasoning was evaluated across 2 experiments with different contexts; Experiment 1 was a low-information environment, and Experiment 2 was a high-information environment. In both experiments, participants supervised a 3-vehicle convoy—his/her manned ground vehicle (MGV), an unmanned aerial vehicle (UAV), and an unmanned ground vehicle (UGV)—as it traversed a simulated environment and rerouted the convoy when needed with the assistance of an intelligent agent. Participants received communications from a commander confirming either the presence or absence of activity along the main route. They also received information regarding potential events along their route via icons that appeared on a map displaying the convoy route and surrounding area. Participants in Experiment 1 (low-information setting) received information about their current route only; they did not receive any information about the suggested alternate route. Participants in Experiment 2 (high-information setting) received information about both their current route and the agent-recommended alternative route. Within each experiment participants were assigned to a level of agent reasoning transparency, and results were compared between subjects to evaluate how the difference in transparency affected operator performance, workload, trust, situation awareness (SA), and complacent behavior. Finally, the 2 experiments' findings were compared to evaluate how differences in available information affected operators' performance at each level of agent reasoning transparency.

The findings of this research are expected to elucidate the interaction between a human's access to the reasoning behind an intelligent agent's actions and the human's knowledge of their task environment. Understanding this relationship and its effect on the human operator's performance, trust in the agent, SA, and workload, as well as the role individual differences play in this interaction, is key to the development of effective human–agent teams.

2. Human–Agent Teaming

A Soldier on the battlefield may be required to conduct multiple concurrent tasks such as maintaining local security and SA and performing threat assessment and identification. While commonplace for Soldiers to concurrently conduct several tasks, switching between tasks causes performance decrements in the primary task when it is interrupted by a secondary task (Cummings 2004; Monsell 2003). Employing robotic assets to assist in these duties allows the Soldier to manage multiple tasks of increasing complexity and expands the Soldier's scope of influence via the robotic capabilities. But, without successful integration of these robotic assets there could be an increase in performance decrements such as reduced SA and increased workload, as shown in previous research into single-operator management of multiple robotic assets (Chen et al. 2008; Wang et al. 2008; Wang et al. 2009). In response to these concerns, an intelligent agent, RoboLeader (RL), was developed to help a human supervisor manage a team of robots (Chen et al. 2010). Several studies have indicated that using an intelligent agent as the point of contact for the robotic team can improve the human operators' SA and task performance and decrease their perceived workload (Chen and Joyner 2009; Chen and Terrence 2009; Wright et al. 2013).

The addition of the intelligent agent to manage the robotic team brings its own unique problems. While the operator benefits from reduced workload, findings indicate they do not always improve on task performance and SA. Chen et al. (2010) found no difference in target-detection performance between the baseline and RL conditions, although there was an improvement in mission-completion times. Similar findings were reported in Wright et al. (2013), in that increasing the RL's level of autonomy (LOA) did not always improve SA or task performance and, in some cases, performance in the highest LOA decreased. This might be due to the occurrence of automation-induced complacency (Parasuraman et al. 1993; Parasuraman et al. 2000). Whether this behavior was due to premature cognitive commitment (Langer 1989) or some other complacent behavior, such as automation bias, or if the operator understood they had insufficient knowledge to appropriately override the automation remained unclear. What is clear is there is still much to learn about human performance issues associated with human–agent teaming.

In the realm of human–automation interaction, a current topic of investigation is the quality of the interaction between the human operator and automated systems; specifically, how the operators' understanding of the system's actions affect their performance and what qualities are contained within the automated system that might enhance this interaction. When the intelligent agent is managing vehicle tasking and route planning or managing vehicles of differing constraints and capabilities, it becomes even more challenging to effectively convey the information to the supervising operator in a manner that allows them to assimilate the information and stay engaged in their supervisory task (Kilgore and Voshell 2014). Transparency of the agent's intent and reasoning may encourage the operator to stay engaged and in the loop, improving performance and reducing complacency. This study investigates complacency associated with human–agent teaming as it pertains to agent reasoning transparency.

2.1 Issues with Automated Systems

An ongoing dilemma in the application of automated systems is task assignment; specifically, which tasks should be automated and which should be performed by the operator (Chapanis 1965; Fitts 1951; Sheridan 2006).

The "Ten Levels of Automation of Decision and Action Selection" model by Parasuraman et al. (2000) defines automation as varying along a continuum of levels, with each level specifying which responsibilities are assigned to the human and which to the automation. While the lowest levels have the human maintaining authority and executing all actions, at each successive level the automation increasingly becomes more autonomous. As the automation level increases, the responsibilities of the human operator decrease, until at the highest level of automation the human no longer has a role. At each increasing level of automation, the operator becomes more removed from the inner loop of control as their role changes from actor to supervisor. Paraphrasing Parasuraman et al. (2000), as the automation level increases from the lowest, Level 1, the responsibilities of the human operator decrease:

- **Lowest**—system offers no aid and human makes all decisions and takes all actions
- System offers a complete set of possible decisions/actions
- System narrows the selection to a few alternatives
- System suggests one alternative
- System executes a suggestion if the human approves
- System gives the human a specified time to veto before its automatic execution

- System executes automatically and then informs the human
- System informs the human only if the human asks
- System informs the human only if the computer decides to inform
- **Highest**— System decides everything, acts on its own, ignores the human

This distance of control eventually creates an "out-of-the-loop (OOTL) condition that leads to increased automation-induced complacency (Parasuraman et al. 1993; Endsley 1996) and reduced operator SA (Parasuraman et al. 1993; Endsley 1995; Chen and Joyner 2009; Chen and Barnes 2010).

2.1.1 Automation-Induced Complacency

Automation-induced complacency is thought to occur when conditions are such that the operator's trait complacency combines with task conditions that favor such complacent behavior, typically in multitasking environments when an operator must divide their attention across multiple tasks (Parasuraman et al. 1993). Complacent behavior occurs when factors create conditions that favor inaction (or continued repetitive action) on the part of the operator. Complacent behavior may be expressed in many ways, such as failure to follow all steps in set procedures or an overload condition causing the operator to attend to one task while (erroneously) entrusting the less than perfectly reliable automation to carry out another (Parasuraman et al. 1993). Operator inexperience, high workload, and consistently reliable systems encourage such overtrust, resulting in more complacent behavior (Parasuraman et al. 1993; Lee and See 2004; Chen and Barnes 2010).

2.1.2 Situation Awareness

SA is defined as "the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future" (Endsley 1988, 1995). This model describes SA as something contained within the individual, separate from yet influenced by individual differences, as well as a function of system design (environment) (Hancock and Diaz 2002). Endsley operationalized the SA model into "levels". Level 1 SA (SA1) is the operators' perception of current situation, Level 2 SA (SA2) is how well the Level 1 SA elements are combined into comprehension of current situation, and Level 3 SA (SA3) is the ability to combine the perception and comprehension from earlier levels into a projection of future state (Endsley 1995). Each level is distinct from the others, yet they have a culmultive nature (e.g., in that SA3 cannot be attained without first achieving SA1). Although we attempt to assess SA at a single point in time, SA is not acquired instantly but developed over time (Endsley 1995). Time is often a critical aspect of SA, both in understanding when an event will occur in the future as well as assessing how relevant information is to

current state. Time is particularly impactful on Levels 2 and 3 SA (see Endsley 1995) as these incorporate understanding of the past to present state awareness for comprehension and projection of future states.

As the level of automation increases the operator becomes more removed from control, creating an "out-of-of-the-loop" situation, resulting in reduced SA (Parasuraman et al. 1993; Endsley 1995; Chen and Joyner 2009; Chen and Barnes 2010). Endsley and Kiris (1995) found that an intermediate level of automation was partially effective in keeping the operator in the loop, increasing operators' Level 1 SA but not their Level 2 SA. This finding indicated the increase in the level of automation encourages a more passive engagement, resulting in reduced understanding that threatens task effectiveness when comprehension and problem-solving are crucial.

2.2 Autonomy

Unlike automated systems, which follow scripts in which all possible courses of action have already been determined, autonomous sytems exercise a degree of choice regarding their actions. They do this using information gathered rather than relying exclusively on information supplied at the design stage (Russell and Norvig 2003). Parasuraman et al.'s (2000) model defines automation in regards to 2 particular aspects of human information processing (Manzey, Reichenbach, and Onnasch 2012). The first is how thoroughly the automation supports the 4 stages of human information processing: information acquisition, information analysis, decision and action selection, and action implementation. The second aspect is how involved the human is in the information processing (and subsequent action taken). The first aspect is assessed within each level of automation. This ranges from simple "detect and react" scenarios to more advanced "analyze inputs, select appropriate action, and execute selected action" decisions. The second aspect is delineated by each successive level of automation (Parasuraman et al. 2000); system autonomy is increasing while human involvement is decreasing, until a point is reached where the system even decides whether to inform the human as to its actions. As such, the levels of automation encompass autonomy, particularly in Levels 5 (concurrence: computer suggests and executes if human approves) and higher, as these levels incorporate a dynamic, self-governing aspect to automation's behavior. The focus in this study is on the decision aspect of autonomy; specifically, the shared decision space between the human operator and the autonomous agent. Consequently, the present focus is on Level 5, or concurrence, automation.

2.3 RoboLeader, An Intelligent Agent

In the computer/artificial-intelligence realm, an agent is defined as capable of perceiving its environment through sensors (e.g., eyes, ears, cameras, proximity switches) and of affecting its environment through actuators (e.g., hands, motors) (Russell and Norvig 2003). An intelligent agent can be human, robot, or even a disembodied entity, such as a computer software program, so long as it is capable of detecting the environment through some sort of input (e.g., hands, eyes, sensors, network packets) and then affecting the environment through some kind of output or actuator (e.g., hands, actuators, information display, network packets). Not only can these intelligent agents be independent, they can also be rational. That is, they interact with their environment in order to achieve a specific goal and measure their success according to specific performance criteria.

One such intelligent agent, RoboLeader, was developed to simplify interactions between a human supervisor and a robotic team (Chen et al. 2010). The human supervisor interacts with the RL, which interprets the supervisor's goals and then commands a team of lower-capability robots through route planning and convoy management. This allows the human to focus on high-level decisions regarding convoy management, freeing their attention for other tasks such as maintaining security and communications. While the addition of the intelligent agent can be a boon to an operator managing multiple tasks, it also creates the distance that makes effective supervision of the team more difficult. Often this "distance" results in the operator displaying automation bias in favor of agent recommendations. It remains unknown whether this bias is a result of the operator recognizing they do not have enough information to confidently override the agent suggestions when appropriate, or whether complacency is due to an operator's OOTL situation. Increasing the transparency of the agent has been recommended as one way to reduce this distance, pulling the operator back into the inner loop of control (Chen et al. 2014). One way to do this is to increase the operator's understanding of the agent's reasoning (i.e., why the agent is making this recommendation).

2.4 Agent Transparency and the SAT model

The human–automation-research community has not yet reached a consensus as to how transparency should be defined. Transparency has been described both as something the automation provides, whether by design or behavior (Kim and Hinds 2006; Cuevas et al. 2007; Cramer et al. 2008), and as the understanding or knowledge an operator has regarding the system's behavior (Jameson et al. 2004; Cheverst et al. 2005; Cring and Lenfestey 2009). When referring to automation or automated systems, early constructs of transparency focused on explaining the

system's behavior in an effort to foster trust. Users begin to question the accuracy and effectiveness of a system when they do not understand the rationale behind the system's recommendations (Linegang et al. 2006). As the users' understanding of the rationale behind a system's behavior grows, the better the users' calibration of their trust and reliance (Lee and See 2004; Lyons 2013; Mercado et al. 2015). The more autonomous that a system becomes, the more important transparency becomes as a factor in user understanding and trust (Dzindolet et al. 2003; Kim and Hinds 2006). A recent definition of agent transparency, "the descriptive quality of an interface pertaining to its abilities to afford an operator's comprehension about an intelligent agent's intent, performance, future plans, and reasoning process" (Chen et al. 2014), expands on earlier constructs by extending the idea of agent transparency beyond simply explaining the agents' behavior and fostering user trust, but also facilitating the operator's comprehension and SA.

The SA-based Agent Transparency (SAT) model (Chen et al. 2014) describes knowledge of what is happening in the environment and the agent's goals as supporting the operator's Level 1 SA (i.e., what is the agent trying to do); understanding the agent's reasoning process as supporting the operators' Level 2 SA (i.e., why does the agent do it); and providing future projections, likelihood of success, and uncertainty information as supporting the operators' Level 3 SA (i.e., what should happen) (Endsley 1995). When the operator knows the agent's intent, understands the agent's reasoning, and can anticipate likely outcomes based on the information and reasoning, the operator can calibrate their trust in the agent (Lee and See 2004). This is particularly important in an evolving environment, where operator goals may not always be in agreement with agent goals (Linegang et al. 2006). When specific environmental information or the agent's reasoning is not available to the operator, the operator has no reason to participate in the decision-making process, thus encouraging a human-OOTL situation (Wickens 1994; Parasuraman et al. 2000), which could contribute to automation-induced complacency (Parasuraman et al. 1993). An OOTL situation is also likely to occur when the operator is conducting multiple tasks in a high-workload environment (Parasuraman et al. 2000). Transparency of the agent's intent and reasoning may encourage the operator to stay engaged and in the loop, improving performance and reducing complacency. The SAT model provides a systematic structure within which the effects of agent transparency can be examined. As such, this study focused on examining the utility of SAT Level 2 information (agent reasoning); specifically, how the transparency of agent reasoning affected the human operator's decision-making ability, as measured via the route-selection task, when the operator has limited knowledge of the task environment. Figure 1 depicts the SAT model.

Fig. 1 SAT model illustrating how agent transparency is defined at each level (Chen et al. 2014)

2.5 Current Study

The present research investigated how the transparency of agent reasoning, within the context of human–agent teaming, influences operator performance and behavior in a dynamic, multitasking environment. The effect of access to agent reasoning was evaluated across 2 experiments with different contexts: Experiment 1 was a low-environmental-information environment and Experiment 2 was a high-information environment. Within each experiment participants were assigned to a level of agent transparency, and results were compared between subjects to evaluate how the difference in transparency affected operator performance, workload, trust, SA, and complacent behavior. Finally, the 2 experiments' findings were compared to evaluate how differences in available information affected operators' performance at each level of agent reasoning transparency.

In each experiment, we simulated a multitasking environment where the operator had to supervise an autonomous agent's route-revision recommendations for a convoy of 3 vehicles—his/her MGV, a UAV, and a UGV—as it proceeded along a predetermined route through a simulated environment. As the convoy travelled its route, events occurred that may have necessitated altering the convoy's route to avoid a potentially hazardous situation. These events included potential threats to the convoy, environmental hazards (e.g., dense fog), and obstacles (e.g., congested traffic). These potential events were indicated by icons that appeared on the map on the operator's control unit (OCU). Operators also had access to intel messages from command, which specified if the events indicated by the map icons were actual threats that required route revision or if the potentially hazardous conditions had cleared and the original route was now safe. When the convoy approached an area with potential events identified, the RL automatically suggested a route revision and the operator had to either accept the suggestion or reject it and keep

the convoy on its original path. The RL's suggestions were correct 66% of the time. Operators needed to recognize and correctly reject any incorrect RL suggestions.

Transparency of the agent's reasoning was manipulated by varying the operator's access to the agents' reasoning. There were 3 agent reasoning transparency (ART) conditions (i.e., ART1, ART2, and ART3). The ART1 condition was the baseline in which the agent notified the operator that a route revision was recommended; however, no agent reasoning for the suggestion was given to the operator. In the ART2 condition, operators had the same information as in ART1 but RL also explained the reason for the suggested route change. In the ART3 condition, operators had the same information as in ART2, but RL also reported when the intel information was received, which gave the operator insight into how stale the information was. In addition to the supervisory duties, participants maintained local security around the convoy via the vehicles' indirect-vision camera feeds by reporting any threats present in the immediate vicinity of the convoy. Participants were also required to maintain SA and received SA queries throughout each trial.

The present results are expected to elucidate how the operators' knowledge of the environment interacts with their understanding of agent reasoning to create "transparency", as well as how increased access to the reasoning behind automation "decisions" affects a human operators' ability to interact effectively with said automation. Too little transparency may hinder human trust in the automation. However, too much may have similarly detrimental effects on operator performance, SA, and decision-making, thus encouraging complacent behavior. In addition, this work investigated how several individual difference factors of common interest within the human–automation-interaction community influence the human–agent relationship in terms of agent transparency, and the subsequent effect on the related human performance issues.

2.5.1 Individual Differences

When evaluating the effectiveness of human–agent teaming, individual differences must be considered. Research has indicated that persons with higher perceived attentional control (PAC) are more effective at allocating attention and less susceptible to performance degradation in a multitasking environment than those with low PAC (Rubinstein et al. 2001; Derryberry and Reed 2002; Chen and Joyner 2009). Previous RL studies found links among PAC, system reliability, and cognitive workload (Chen and Terrence 2009; Wright et al. 2013). Differential effects on performance due to spatial ability (SpA) have been found on teleoperation tasks, robotic operation, and target-detection tasks (Lathan and Tracey 2002; Chen et al. 2008; Chen et al. 2010), as well as improved SA and

target-detection performance (Fincannon 2013; Wright et al. 2013). Working memory capacity (WMC) differences have been shown to affect performance in multirobot supervisory tasks (Ahmed et al. 2014) and SA (Endsley 1995; Wickens and Holland 2000). In the current experiment, we examined the differential effects of PAC, SpA, and WMC on multitasking performance, operator SA, and perceived workload. Complacency Potential (CP) affects an individual's ability to adequately monitor automation and to detect automation failures, so it was assessed using the Complacency Potential Rating Scale (CPRS) (Singh et al. 1993; Pop and Stearman 2015) as a possible mediating factor on the route-selection task. WMC has been shown to correlate with an individual's attentional control (Engle et al. 1999), so WMC was evaluated as a covariate for assessing individual differences in performance due to PAC and SpA.

2.5.2 Eye-Tracking Measures

It has been asserted that underlying cognitive activities can be reliably inferred from eye-tracking metrics (Beatty 1980; Jacob and Karn 2003). In an earlier RL study (Wright et al. 2013), eye-tracking metrics proved useful in evaluating differences in workload that subjective measures of workload did not reveal. This work incorporates 3 visual measures as objective measures of cognitive workload: 1) fixation count, 2) fixation duration, and 3) pupil diameter.

2.5.2.1 Fixation Count (FC)

Fixations are low-velocity eye movements that correspond to a person staring at a particular point. The number of fixations, FC, has been shown to correlate positively with search difficulty (Ehmke and Wilson 2007) and negatively with search efficiency and increased mental workload (Goldberg and Kotval 1999; Van Orden et al. 2000).

2.5.2.2 Fixation Duration (FD)

The FD is the period of time the eye remains relatively still. In general, longer fixations times are associated with deeper cognitive processing. Studies have shown that longer fixation duration implies more mental processing (Unema and Rotting 1990) and increased search difficulty (Goldberg and Kotval 1999), however vigilance studies have indicated that longer fixation duration could also be an indicator of disinterest or daydreaming (Chapman and Underwood 1998).

2.5.2.3 Pupil Diameter (PDia)

Pupil size is sensitive to lighting changes, view angles, and distance to the screen, and is measured by imposing an ellipse over the pupil and measuring the vertical

and horizontal axes (Holmqvist et al. 2011). Increases in pupil diameter have been found to be positively correlated with increased mental workload and interest (Beatty 1980; Peavler 1974; Van Orden et al. 2001).

3. Experiment 1

3.1 Overview

Experiment 1 investigated how access to agent reasoning affected the human operator's decision-making, task performance, SA, and complacent behavior in a multitasking environment when limited environmental information was available. The participants' role was to supervise a convoy of vehicles as it progressed through a simulated environment, maintaining communications with command and identifying potential threats along the way. A map of the area was provided with a predetermined route marked. Icons referring to potentially hazardous events along the preplanned route appeared on the map (Fig. 2). When approaching such an area, RL suggested altering the route and the participant either accepted or rejected the suggestion. No information was provided about the proposed alternate route. The amount of ART behind RL's recommendation was manipulated between participants, varying from simple notifications to text reports that included the time RL received the information that was the basis for its recommendation. Each participant completed 3 missions at a specific ART. As the convoy progressed through the simulated environment, the participants maintained communication with command, receiving incoming messages and responding when appropriate (SA probes). While overseeing the convoy's progress, the participants concurrently conducted a target-detection task by monitoring the vehicles' camera feed and identifying potential threats in their environment. The number of threats was held constant across routes.

Fig. 2 Icon indicates a potential event on the convoy's main route (solid line), and the proposed alternative route (dashed lines)

3.2 Stated Hypotheses

3.2.1 Complacent Behavior, Primary Task Performance, Trust in the Agent

We hypothesized that access to agent reasoning would reduce complacent behavior, improve task performance, and increase trust in the agent—but only to a degree, beyond which increased access to agent reasoning would result in information overload that would negatively impact performance, increase complacent behavior, and reduce trust in the agent (i.e., ART1 < ART2 > ART3). It has been previously stated that high attentional demands can cause aftereffects similar to those resulting from high stress (Cohen 1980); as such, this hypothesis resembles an inverted (extended) U-shaped function often observed in operators in stressful conditions (Hancock and Warm 1989; Yerkes and Dodson 1908). Decision time was also examined as a facet of performance and as such was expected to increase as access to agent reasoning increased: ART1 < ART2 < ART3. Although RL's messages were slightly longer in ARTs 2 and 3 than in ART1, the difference in reading time is expected to be negligible. Participants were expected to take longer to process the information and reach their decision, resulting in longer decision times. We hypothesize that shorter response times indicate less deliberation on the part of the operator before accepting or rejecting the agent recommendation, indicating complacent behavior.

Hypothesis 1: Access to agent reasoning will reduce incorrect acceptances, ART1 > ART2, and increased transparency of agent reasoning will increase incorrect

acceptances, ART2 < ART3. When agent reasoning is not available, incorrect acceptances will be greater than when agent reasoning is present, ART1 > ART2+3 (combined result of conditions with agent reasoning transparency).

Hypothesis 2: Access to agent reasoning will improve performance (number of correct rejections and acceptances) on the route-selection task, ART1 < ART2, and increased transparency of agent reasoning will reduce performance on the route-selection task, ART2 > ART3. When agent reasoning is not available, performance will be lower than when agent reasoning is present, ART1 < ART2+3.

Hypothesis 3: Access to agent reasoning will increase operator trust in the agent, ART1 < ART2, and increased transparency of agent reasoning will decrease operator trust in the agent, ART2 > ART3.

3.2.2 Workload

We hypothesize that increasing agent reasoning transparency will in turn increase the operators' workload. Typically, increased automation assistance reduces operator workload, as the operator is able to offload a portion of their duties to the automation. However, in the case of agent reasoning transparency, the amount of information the operator must process increases as the agent reasoning becomes more transparent. It is expected that this increased mental demand will be reflected in the workload measures.

Hypothesis 4: Access to agent reasoning will increase operator workload, ART1 < ART2; and increased transparency of agent reasoning will increase operator workload, ART2 < ART3. When agent reasoning is not available, workload will be lower than when agent reasoning is present, ART1 < ART2+3.

3.2.3 SA

We hypothesize that agent reasoning transparency will support operator SA. Access to the agent reasoning will help the operator better comprehend how objects/events in the task environment affect their mission, thus informing their task of monitoring the environment surrounding the convoy and making them cognizant of potential risks. This understanding will also enable them to make more accurate projections regarding future safety of their convoy. However, the addition of information that appears ambiguous to the operator will have a detrimental effect on their ability to correctly project future status.

Hypothesis 5: Access to agent reasoning will improve SA scores; increased transparency of agent reasoning will improve SA1 and SA2 scores, but will reduce SA3 scores:

- SA1: ART1 < ART2, ART2 < ART3
- SA2: ART1 < ART2, ART2 < ART3
- SA3: ART1 < ART2, ART2 > ART3.

3.2.4 Target-Detection Task Performance

We hypothesize that increasing agent reasoning transparency will reduce performance on the target-detection task. The increased mental demand on the operator will affect their ability to effectively monitor the environment for threats. However, access to agent reasoning will allow operators' to maintain higher selection criteria, resulting in fewer false alarms (FA).

Hypothesis 6: Access to agent reasoning will reduce the number of targets detected and the number of FAs on the secondary task, ART1 > ART2; increased transparency of agent reasoning will reduce the number of targets detected and the number of FAs, ART2 > ART3.

3.2.5 Individual Differences

The effects of individual differences in CP, PAC, SpA, and WMC on the operator's task performance, trust, and SA were also investigated.

Hypothesis 7: Higher-CP individuals will have fewer correct rejections on the route planning task than lower-CP individuals.

Hypothesis 8: Higher-CP individuals will have higher scores on the usability and trust survey than lower-CP individuals.

Hypothesis 9: Higher-CP individuals will have lower SA scores than lower-CP individuals.

Hypothesis 10: Individual differences, such as SpA and PAC, will have differential effects on the operator's performance on the route-selection task and their ability to maintain SA.

Hypothesis 11: Higher-WMC individuals will have more correct rejections and higher SA2 and SA3 scores than lower-WMC individuals.

3.3 Method

3.3.1 Participants

Seventy-six participants (ages 18–40) were recruited from the Sona System in the University of Central Florida's (UCF) Institute for Simulation and Training and

Psychology Department. UCF's Sona System is a participant-recruitment system that allows students and members of the local community to participate in research. Participants received their choice of compensation: either cash payment ($15/hr) or Sona Credit at the rate of 1 credit/hr. Sixteen potential participants were excused or dismissed from the study, of which 9 left early due to equipment malfunctions, one withdrew during training claiming insufficient time to participate, 3 fell asleep during their session, 2 could not pass the training assessments, and one did not pass the color-vision screening test. Those who were determined to be ineligible or withdrew from the experiment received payment for the amount of time they participated, with a minimum of one hour's pay. Sixty participants (26 males, 33 females, 1 unreported; Min_{age} = 18 years, Max_{age} = 32 years, M_{age} = 21.4 years) successfully completed the experiment, and their data were used in the analysis.

3.3.2 Apparatus

3.3.2.1 Simulator

The Mixed Initiative Experimental (MIX) Testbed (Fig. 3) was used for this experiment. The MIX Testbed is a distributed simulation environment for researching how unmanned systems are used and how automation affects human operator performance (Barber et al. 2008). This platform includes a camera payload and supports multiple levels of automation. Users can send mission plans or teleoperate the platform with a computer mouse while observing a video feed from the camera payload. Typical tasks include reconnaissance and surveillance. RoboLeader has the capability of collecting information from subordinate robots with limited autonomy (e.g., collision avoidance and self-guidance capabilities), making tactical decisions, and coordinating the robots by issuing commands, waypoints, or motion trajectories (Chen et al. 2010). The simulation was modified from the experimental design described by Wright et al. (2013) and delivered via a commercial desktop computer system, 22-inch monitor, standard keyboard, and 3-button mouse.

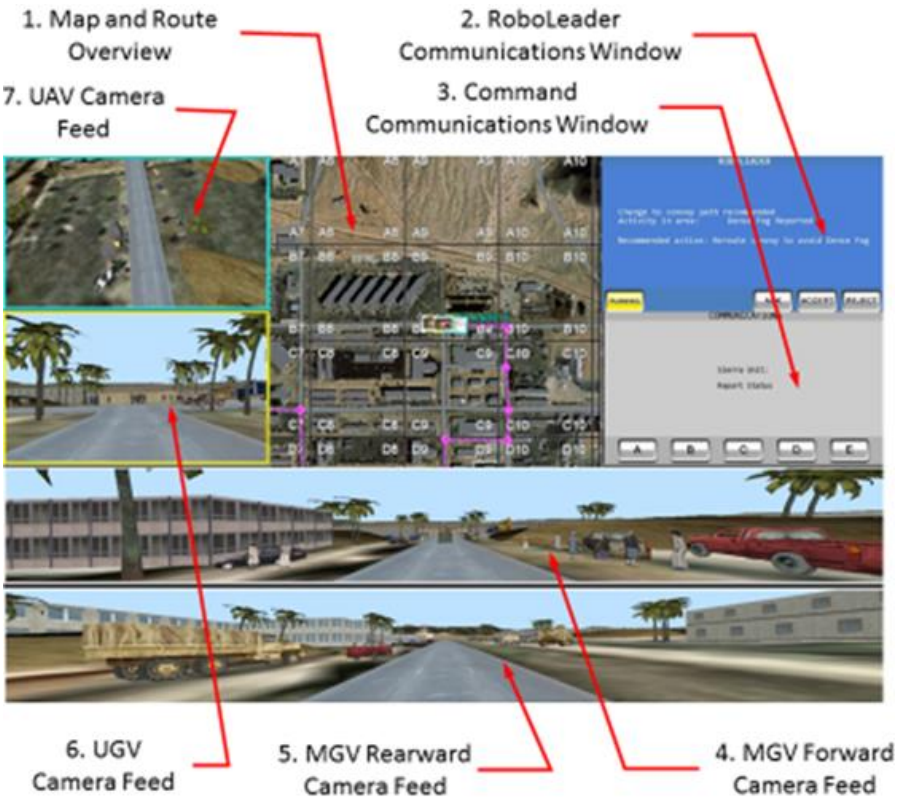

Fig. 3 The operator's control unit is the user interface for convoy management and 360° tasking environment. OCU windows are (clockwise from the upper center) map and route overview, RL communications window, command communications window, MGV's forward 180° camera feed, MGV's rearward 180° camera feed, UGV's forward camera feed, and UAV's camera feed.

3.3.2.2 Eye Tracker

The Sensomotoric Instrument (SMI) Remote Eyetracking Device (RED) was used to collect eye-movement data. The SMI–RED system uses an IR-camera-based tracking system, which allows noncontact operation. Eye and head movements, which can be observed at approximately 0.03° of spatial resolution and sampled at the rate of 120 Hz, along with measurement-reliability data were logged in real time and synchronized with performance data from other systems. Only the participants' eye-gaze coordinates were measured and recorded; no video of the participants' eyes and faces was recorded. The system was individually calibrated for each participant before each scenario.

3.3.3 Surveys and Tests

3.3.3.1 Demographics Questionnaire

A demographics questionnaire was administered at the beginning of the training session (see Appendix A). Information on participant's age, gender, education level, computer familiarity, and gaming experience was collected.

3.3.3.2 Ishihara Color Vision Test

An Ishihara Color Vision Test comprising 9 test plates (Ishihara 1917) was administered via PowerPoint slide presentation. Since the RL's OCU employs several colors to display the plans for the robots, normal color vision is required to effectively interact with the system. One potential participant failed to correctly identify at least 7 of the plates and was paid for 1 hr and dismissed.

3.3.3.3 Attentional Control Survey

A questionnaire on Attentional Control (Derryberry and Reed 2002) was used to measure participants' PAC (see Appendix B) by evaluating their perception of their attention focus and shifting. The Attentional Control survey consists of 20 items scored on a 1–4-point Likert scale, with half of the items reverse-scored. Score range is 20–80 points, with higher scores indicating better attentional control. The scale has been shown to have good internal reliability ($\alpha = .88$). High/low group membership by number (N) was determined by median (Mdn) split of all participants' scores ($Min_{PAC} = 41.0$, $Max_{PAC} = 74.0$, $Mdn_{PAC} = 61.0$, $M_{PAC} = 60.5$, $SD_{PAC} = 7.5$; PAC_{LOW} $N = 28$, PAC_{HIGH} $N = 32$).

3.3.3.4 Spatial Ability Tests

The Cube Comparison Test (Ekstrom et al. 1976) assesses the spatial ability factor known as spatial visualization (SV) by measuring an individual's ability to mentally manipulate objects in 3-D space. (See Appendix C.) It consists of 2 parts and requires participants to compare, in 3 min per part, 21 pairs of 6-sided cubes and determine if the rotated cubes are the same or different. Each part was scored using the formula

$$\left[\left(\frac{\#attempted}{21}\right)\left(\frac{\#correct}{\#answered}\right)\right] * 100, \quad (1)$$

where attempted items included both answered and skipped items, answered items included any item where an answer was supplied (whether correct or incorrect), and skipped items were items that were not answered but were followed by at least one answered item. The scores of the 2 parts were then averaged to give the participants' overall score. Higher scores imply greater SV ability. High/low group membership was determined by median split of all participants' scores ($Min_{SV} = 0.234$, $Max_{SV} = 0.95$, $Mdn_{SV} = 0.60$, $M_{SV} = 0.61$, $SD_{SV} = 0.18$, SV_{LOW} $N = 30$, SV_{HIGH} $N = 30$).

The Spatial Orientation Test (SOT) measures an individual's ability to orient themselves in a 3-D world (Gugerty and Brooks 2004). It is a computerized test consisting of a brief training segment and 32 test questions whose score is based on both accuracy and response time. Scores are calculated by dividing average

response time by total number correct, and higher performance is indicated by lower scores. (See Appendix D.) High/low group membership was determined by median split of all participants' scores (Min_{SOT} = 3.97, Max_{SOT} = 39.32, Mdn_{SOT} = 12.72, M_{SOT} = 14.15, SD_{SOT} = 8.41, SOT_{LOW} N = 27, SOT_{HIGH} N = 33).

3.3.3.5 National Aeronautics and Space Administration-Task Load Index (NASA-TLX)

Participants' perceived workload was evaluated with the computerized version of the NASA-TLX questionnaire, which uses a pairwise comparison weighting procedure (Hart and Staveland 1988). The NASA-TLX is a self-reported questionnaire of perceived demands in 6 areas: mental demand, physical demand, temporal demand, effort (mental and physical), frustration, and performance. Participants evaluated their perceived workload in these areas on 10-point scales as well as completing pairwise comparisons for each subscale. (See Appendix E.)

3.3.3.6 Complacency Potential Rating Scale

The updated CPRS (Singh et al. 1993; Pop and Stearman 2015) measures an individual's attitude toward automation and automated devices and has been shown to have high internal consistency (r > .98) and test–retest reliability (r = .90). The CPRS has 20 items, 4 of which are filler, and each item is scored from 1 ("Strongly agree") to 5 ("Strongly disagree"). Several items are negatively worded and are reverse-scored in the final tally. (See Appendix F.) CPRS scores range from 16 (low complacency potential) to 80 (high complacency potential). The developers suggest classifying participants as either low or high complacency potential using the median split of the CPRS scores. High/low group membership was determined by median split of all participants' scores (Min_{CPRS} = 28.0, Max_{CPRS} = 49.0, Mdn_{CPRS} = 39.5, M_{CPRS} = 39.9, $CPRS_{LOW}$ N = 30, $CPRS_{HIGH}$ N = 30).

3.3.3.7 Reading Span Task (RSPAN)

Verbal WMC was assessed using the automated RSPAN (Daneman and Carpenter 1980; Unsworth et al. 2005; Redick et al. 2012), which has high internal (partial score α = .86) and test-retest (α = .82) reliability. (See Appendix G.) Participants were shown a sentence and determined if the sentence made sense as written (e.g., "Andy was stopped by the policeman because he crossed the yellow heaven"). When viewing the sentence, they answered "Yes" (the sentence makes sense) or "No" (the sentence does not make sense). Participants were given feedback how they were performing on this task and were instructed to keep their performance above 80%. A minimum score of 80% correct on the sentence-comprehension portion was required to continue with the study. However, no participants were

dismissed. After evaluating the sentence, they were shown a letter to be recalled later. At the end of each set, participants were prompted to recall the letters in the proper order. Sentence–letter set sizes varied between 3 and 6 items, and each participant received 3 sets of each set size, for a total of 54 sentence–letter sets. WMC was evaluated by using the participants' letter-set score (total number of letters in perfectly recalled letter sets), and higher values indicate greater WMC (Min_{RSPAN} = 5.0, Max_{RSPAN} = 51.0, Mdn_{RSPAN} = 32.5, M_{RSPAN} = 31.3, SD_{RSPAN} = 11.1). High/low group membership was determined by median split of all participants' scores, $RSPAN_{LOW}$ N = 30, $RSPAN_{HIGH}$ N = 30.

3.3.3.8 Usability and Trust Survey

Participants' perceived usability of and trust in the system were evaluated using a modified version of the Usability and Trust Survey (Chen and Barnes 2012). The survey consists of 20 questions rated on a scale of 1 to 7, with an overall scoring range of 20–140 points. (See Appendix H.) Items 1–8 assess usability (score range 8–56) while items 9–20 assess trust (score range 12–84). Negative questions such as "The RoboLeader display was confusing" were reverse coded (e.g., a score of 7 = 1, 6 = 2). Positive questions such as "The RoboLeader system is dependable" and "I can trust the RoboLeader system" were regularly coded, with the sums of the positive and inverse-scored negative questions combined to create a global score. Higher scores indicate greater trust and better usability.

3.3.4 Experimental Design and Performance Measures

The study was a between-subjects experiment. Independent variables were ART level and individual-difference factors. Dependent measures were route-selection task score, decision time, target-detection task scores, workload, SA, and trust scores.

3.3.4.1 Independent Variables

ART was manipulated via RL messages (see Appendix K). In ART1 the agent recommended a course of action but otherwise offered no insight as to the reasoning behind the recommendation. In ART2 the agent recommended a course of action and gave the reason behind this recommendation. In ART3 the agent's recommendation was the same as in ART2. However, the message also said how long ago the information was received (e.g., 1 hr, 4 hr, 6 hr). Participants completed 3 missions in their assigned ART.

3.3.4.2 Dependent Measures

3.3.4.2.1 Route-Selection Task Measures

- Performance Score: Participants were scored on whether they correctly accepted or rejected RL's route selection, and those scores summed across all missions. The score range for this score is 0 (no correct rejections or acceptances) to 18 (correctly accepted or rejected all RL suggestions).

- Complacent behavior was operationalized in this study as automation bias (complacency in decision-making) and was evaluated as accepting RL's route suggestion when it was not correct. Twice each mission, RL made a suggestion that should be rejected. Incorrect acceptances of these suggestions were indicative of complacent behavior; the participant scored 1 point for each incorrect "accept" and these were summed across all missions. The score range for this measure is 0–6, with higher scores indicating more complacent behavior and lower scores indicating less. Decision time was assessed concurrently in order to better distinguish between complacent behavior and simple errors. Reduced decision times, particularly when ART increases, could indicate less deliberation (i.e. more complacent behavior).

- Incorrect Rejections: Four times each mission RL made a suggestion that should have been correctly accepted. Incorrect rejections of these suggestions were indicative of low trust and/or poor SA; the participant scored 1 point for each incorrect reject, and these were summed across all missions. The score range for this measure is 0–12, with higher scores indicating more distrustful behavior and lower scores indicating less.

- Decision Time (DT): DT was averaged across missions. DT was quantified as the time between agent alert and participant route selection. Reduced DT when ART was available or increased (compared to DT in the notification-only condition) could indicate overwork resulting in complacent behavior.

3.3.4.2.2 Target-Detection Task Measures

- Targets Detected (Hits): Number of targets correctly identified was expected to decrease as access to agent reasoning increased.

- False Alarms: Number of FAs was expected to increase as ART increases.

- In addition to hits and FAs, 2 signal-detection theory measures were used to assess participant performance on the target-detection task:

    - d'—A measure of sensitivity to target. Values near 0 indicate correct detection probability near chance while higher values indicate increased discernibility of targets and participant sensitivity to targets.

- β—The likelihood ratio, an area-based measure of response bias. Higher values indicate a more conservative response bias.

3.3.4.2.3 SA Scores

In this study, the agent's level of automation is kept at an intermediate LOA to control the effects of information and reasoning, and the state of the operator's SA is assessed via real-time probes that appear as requests for information from "command". The Level 1 SA probes enquire about objects and persons in the simulated environment, with the idea that elements within the environment influence the participants' responses (Hancock and Diaz 2002). The Level 2 SA probes enquire about the reasoning behind the participants' choices in an attempt to gauge their understanding and comprehension of the events in the environment that should influence their decision. The Level 3 SA probes ask the participant to project the future status of their convoy based upon their understanding of upcoming threats along their route.

Each mission contained 18 SA queries, 6 for each of the 3 SA levels. SA queries were designed to assess the participants' SA at a specific SA level (i.e., SA1—Level 1 SA, perception; SA2—Level 2 SA, reasoning, comprehension; SA3—Level 3 SA, the projection of future state). Higher scores indicate better SA. (See Appendix L.)

3.3.4.2.4 Trust

After completing 3 missions, the Usability and Trust Survey was administered to assess the participants' trust in the agent.

3.3.4.2.5 Workload

Perceived Workload: After completing 3 missions, the NASA-TLX was administered to assess the participants' perceived workload. Both global and individual factor workload scores were evaluated.

Cognitive Workload: This was evaluated using several ocular indices (i.e., fixation count, fixation duration, pupil diameter). Data for these measures was collected at a sampling rate of 120 Hz over the length of each mission, and then averaged across all missions.

3.3.5 Procedure

After being briefed on the purpose of the study and signing the informed-consent form (see Appendix I), participants completed the demographics questionnaire, the RSPAN, and a brief Ishihara Color Vision Test. Then participants completed the Attentional Control Survey, the Cube Comparisons test, the SOT, and the CPRS.

Participants then received training and practice on their tasks. Training was self-paced and delivered by PowerPoint slides (see Appendix J). Participants were trained on the elements of the OCU, identification of map icons and their meanings, and steps for completing various tasks and then completed several mini-exercises for practice. The training session lasted approximately 1.5 hr. Before proceeding to the experimental session, participants had to demonstrate they could recall all icons and their meanings, as well as perform all tasks, without any help. Participants were required to score 90% proficiency on the assessments; those who scored too low on the assessments were allowed to review the information again. If after additional training the participant could not pass the asssessments, they were paid for the time they had spent in the experiment and dismissed.

The experimental session lasted approximately 2 hr and began immediately after the training session. Participants were randomly assigned to an ART condition (ART1, ART2, or ART3), which was counterbalanced across participants to ensure an equal N in each condition. The experimental session had 3 scenarios. Each scenario consisted of a different convoy route through the same simulated environment and lasted approximately 30 min. The scenario order was counterbalanced across participants to avoid order effects. At the beginning of each scenario, the eye tracker was calibrated using the 9-point calibration setting.

During the scenarios, participants guided a convoy of 3 vehicles (their own MGV, a UAV, and a UGV) through a simulated urban environment, moving from checkpoint to checkpoint along a preplanned route. As the convoy proceeded through the environment, events occurred that necessitated altering the route. Information regarding potential events along the preplanned route, together with communications from a commander confirming either the presence or absence of activity in the area, were provided to all participants. They did not receive any information about the suggested alternate route. However, they were instructed that the proposed path was at least as safe as their original route. When the convoy approached a potentially unsafe area, the intelligent agent would recommend rerouting the convoy. Each scenario had 6 events that caused RoboLeader to suggest a route revision. Events and their associated area of influence were displayed on the map with icons. The participants viewed communications from RL (see Appendix K) via a text feed in the upper right-hand corner of the OCU. The RL suggested a potential route revision, and the operator either had to accept or reject the suggestion. Two of RL's route-change suggestions per scenario were inappropriate (66% reliable), which the participant needed to correctly reject. Once RL suggested a route, there was a limited amount of time (15 s) for the participant to acknowledge the suggested change, which they did by clicking the "acknowledge" button on the RL-communication window. If time expired before

the participant acknowledged RL's suggestion, RL automatically continued convoy movement along the original route; however, all participants acknowledged RL's suggestion within the allotted time. Once the participant acknowledged RL's suggestion, the simulation paused until the participant either agreed with or rejected RL's suggestion.

The participant maintained communication with their command via a text feed directly below RL's communication window. Participants viewed messages from command, not all of which were directed to the participant. Each mission contained 12 information updates from command, 2 of which would result in the need to override RoboLeader's route recommendation. Communications included messages directed at other units (e.g., "Lima Unit: Return to rally point"), which the participant should have disregarded. These messages were intended to create "noise" as well as maintain a consistent rate for incoming messages (one message from either source approximately every 30 s). In all conditions, command would also request information from the operator (SA queries). Requests for information required a response from the participant, which they did by selecting the appropriate response in the communication window on the OCU. Each mission contained 18 requests for information, and these were used to assess the participants SA.

Simultaneously, the participants had to maintain local security surrounding his/her MGV by monitoring the MGV and UGV indirect-vision displays and detect targets in the immediate environment. Once a hostile target was detected, the participants identified the target by clicking on it with the mouse. Mouse clicks in the camera feed windows produced a camera-shutter sound, so the participant had verification that they did successfully click in the window. However, they did not receive feedback regarding their performance on the target-detection task. There were civilians and friendly dismounted soldiers in the simulated environment to increase the visual noise present in the target-detection tasks.

After completing 3 missions, participants assessed their perceived workload and trust in RL's suggestions. Participants were then debriefed, and any questions they had were answered by the experimenter.

3.4 Results

Data analysis was performed using SPSS Version 22 software. Data were examined using planned comparisons ($\alpha = .05$), using a Bonferroni correction for multiple comparisons when applicable. When there was a violation of the homogeneity of variance assumption, Welch's correction was used and contrast tests did not assume equal variance between conditions. Specifically, ART1 was compared to ART2, ART2 to ART3, and ART1 to ART2+3 (average of ART2 and ART3 scores) unless

otherwise noted. Means, standard deviation (SD), and 95% confidence intervals (CI) are reported for each measure.

Categorical data, such as grouped participant responses, were evaluated using Chi-squared analysis ($\alpha = .05$).

Individual difference (ID) factors (i.e., SpA, PAC, and WMC) were assessed as potential covariates for all dependent measures. When an ID factor was revealed to be a significant predictor or correlate highly with the measure of interest, these results were reported. However, none passed the heterogeneity of regression requirement for use as a covariate in an analysis of covariance.

Preliminary GPower 3.1.3 analysis indicated that 60 participants, in 3 groups (20 per group), in a between-factors analysis of variance (ANOVA) had an estimated power of .83 at a medium-to-large effect size ($f = .35$).

3.4.1 Complacent behavior, Primary Task Performance, Trust in the Agent

3.4.1.1 Complacent Behavior

Hypothesis 1: Access to agent reasoning will reduce incorrect acceptances, ART1 > ART2, and increased transparency of agent reasoning will increase incorrect acceptances, ART2 < ART3. When agent reasoning is not available, incorrect acceptances will be greater than when agent reasoning is present, ART1 > ART2+3.

Descriptive statistics for incorrect acceptances and decision times at the locations where the agent recommendation should have been rejected are shown in Table 1.

Table 1 Descriptive statistics for incorrect acceptances and decision times, sorted by ART level (with SE = standard error and CI = confidence interval)

		N	Mean	SD	SE	95% CI for mean
Incorrect acceptances	ART1	20	3.25	2.27	0.51	(2.19, 4.31)
	ART2	20	1.14	1.28	0.29	(0.54, 1.73)
	ART3	20	2.65	2.32	0.52	(1.56, 3.74)
Overall DT at reject locations (s)	ART1	20	3.82	1.88	0.42	(2.94, 4.70)
	ART2	20	2.96	1.44	0.32	(2.29, 3.64)
	ART3	20	3.41	1.55	0.35	(2.69, 4.14)
DT correct rejects (s)	ART1	14	7.47	4.29	1.15	(4.99, 9.95)
	ART2	20	7.49	3.17	0.71	(6.01, 8.98)
	ART3	18	8.14	3.47	0.82	(6.41, 9.86)
DT incorrect accepts (s)	ART1	18	8.04	2.86	0.67	(6.62, 9.46)
	ART2	11	6.09	1.76	0.53	(4.91, 7.28)
	ART3	14	7.90	3.20	0.86	(6.06, 9.75)

Planned comparisons revealed that mean incorrect acceptances were lower in ART2 than in ART1, $t(29.9) = -3.63$, $p = .001$, $r_c = .55$, and ART3, $t(29.5) = 2.55$, $p = .016$, $r_c = .43$ (see Fig. 4). Overall, incorrect acceptances were significantly lower when agent reasoning was provided (ART1 > ART2+3), $t(31.8) = -2.31$, $p = .028$, $r_c = .38$. The hypothesis was supported, since access to agent reasoning did reduce incorrect acceptances in a low-information environment, and increased transparency of agent reasoning began to overwhelm participants resulting in increased incorrect acceptances.

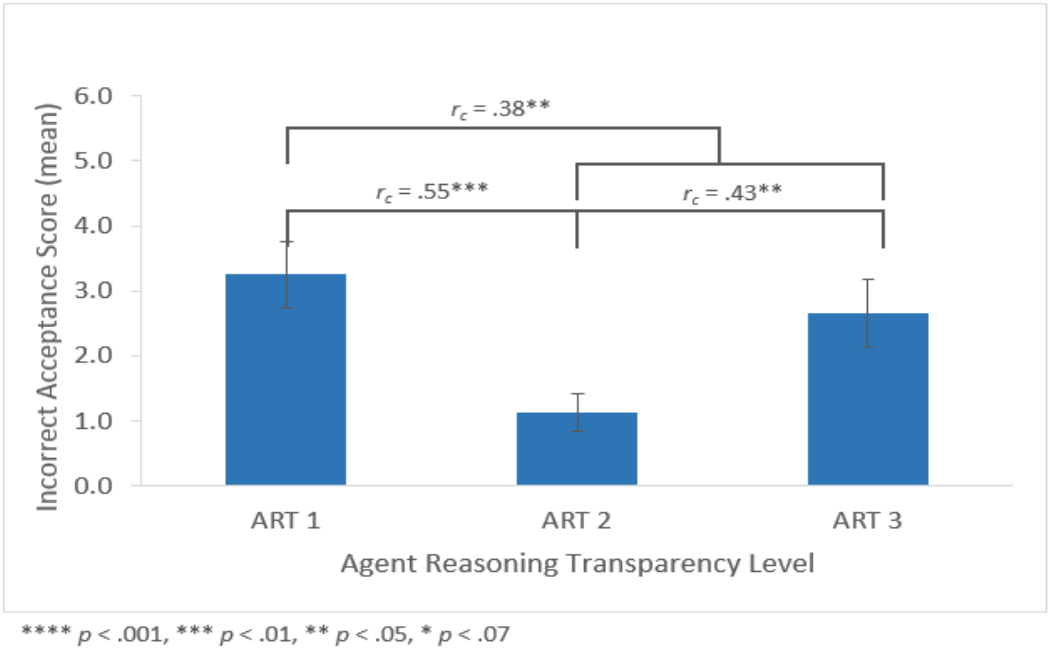

Fig. 4 Average incorrect acceptances by ART level; bars denote SE

Complacent behavior could also be indicated by reduced DT for responses on the route-selection task, particularly at those locations where the agent recommendation is incorrect. We hypothesized that DT would increase as ART increased, as participants should require additional time to process the extra information. Thus, reduced time could indicate less time spent on deliberation, which could be an indication of complacent behavior. In addition to the overall time to respond, DTs for correct rejections and incorrect acceptances were also examined (Fig. 5).

There was no significant difference in overall DTs, nor for DTs for correct rejections among the ART levels. However, DTs for incorrect acceptances were longer in ART1 than in ART2, $t(27.0) = -2.27$, $p = .032$, $r_c = .40$, and shorter in ART2 than in ART3, $t(20.9) = 1.80$, $p = .087$, $r_c = .37$. While overall DTs remain relatively unchanged across ART levels, DTs for incorrect acceptances drop significantly in ART2, which could be an indication of less deliberation and potentially complacent behavior. Paired t-tests were used to compare differences between DTs for correct and incorrect responses within each ART; however, none were found to be statistically significant.

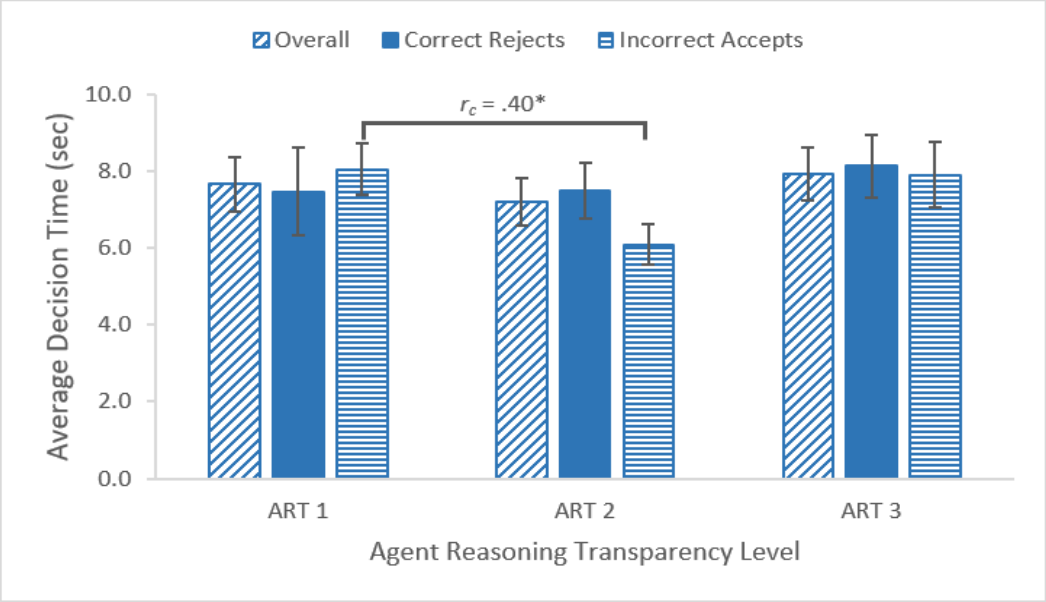

Fig. 5 Average DT in seconds for participant responses at decision points where the agent recommendation was incorrect: DTs are shown for all responses (overall), correct rejections, and incorrect acceptances, sorted by ART level; bars denote SE.

Participants' responses were further analyzed by the number of incorrect acceptances per ART level (Fig. 6). In total, 17 participants had no incorrect acceptances, 15 of whom were in ARTs 2 and 3—evidence that access to agent

reasoning was beneficial in avoiding incorrect acceptances. Chi-square analysis found a significant effect of ART on the number of incorrect acceptances, $X^2(14) = 29.45$, $p = .009$, Cramer's $V = .495$. Forty-three participants had at least one incorrect acceptance; 42% of these were in ART1, 32% in ART3, and 26% in ART2. The incorrect scores were sorted into groups: <50% (score 3 or less) or >50% (score 4 or higher). Participants in ART1 were evenly split between these groups, indicating that in the notification-only condition performance was no better than chance. Also, of the 8 participants who scored 6/6 on incorrect acceptances, 6 were in ART1. The majority of participants who had >50% incorrect acceptances when agent reasoning was available were in ART3. An examination of the distribution of scores shows that access to agent reasoning had a beneficial effect on performance. However, the increase in incorrect acceptances in ART3 could indicate too much access to agent reasoning can have a detrimental effect on performance.

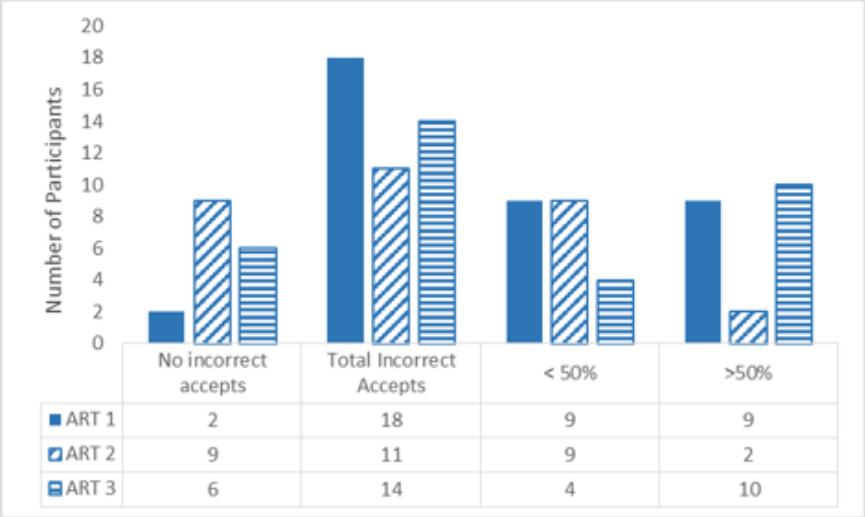

Fig. 6 Distribution of incorrect acceptance scores across ART levels

3.4.1.2 Route-Selection Task Performance

Hypothesis 2: Access to agent reasoning will improve performance (total number of correct rejections and acceptances) on the route-selection task, ART1 < ART2, and increased transparency of agent reasoning will reduce performance on the route-selection task, ART2 > ART3. When agent reasoning is not available performance will be lower than when agent reasoning is present, ART1 < ART2+3.

Descriptive statistics for route-selection task scores and DTs for all decision points across 3 missions are shown in Table 2.

Table 2 Descriptive statistics for route-selection scores and DTs, sorted by ART level

		N	Mean	SD	SE	95% CI for mean
Route-selection score	ART1	20	14.10	2.59	0.58	(12.89, 15.31)
	ART2	20	15.70	2.23	0.50	(14.66, 16.74)
	ART3	20	14.70	2.81	0.63	(13.38, 16.02)
Overall DT	ART1	20	7.64	3.60	0.81	(5.95, 9.32)
	ART2	20	7.51	3.36	0.75	(5.93, 9.08)
	ART3	20	8.14	3.62	0.81	(6.45, 9.84)
DT correct responses	ART1	20	7.53	3.52	0.79	(5.88, 9.18)
	ART2	20	7.42	3.37	0.75	(5.85, 9.00)
	ART3	20	7.98	3.33	0.74	(6.43, 9.54)
DT correct responses	ART1	18	8.02	2.80	0.66	(6.63, 9.42)
	ART2	17	8.44	4.20	1.02	(6.28, 10.60)
	ART3	14	9.16	5.20	1.39	(6.16, 12.16)

Planned comparisons revealed that mean route-selection task scores were higher in ART2 than in ART1, $t(57) = 1.98$, $p = .053$, $r_c = .25$ (see Fig. 7). The hypothesis was partially supported, as the medium–large-effect size between ARTs 1 and 2 indicates the addition of agent reasoning did improve route-selection performance. Scores in ART3 were somewhat lower than those in ART2; however, this difference was not significant, indicating performance in these 2 conditions was essentially the same.

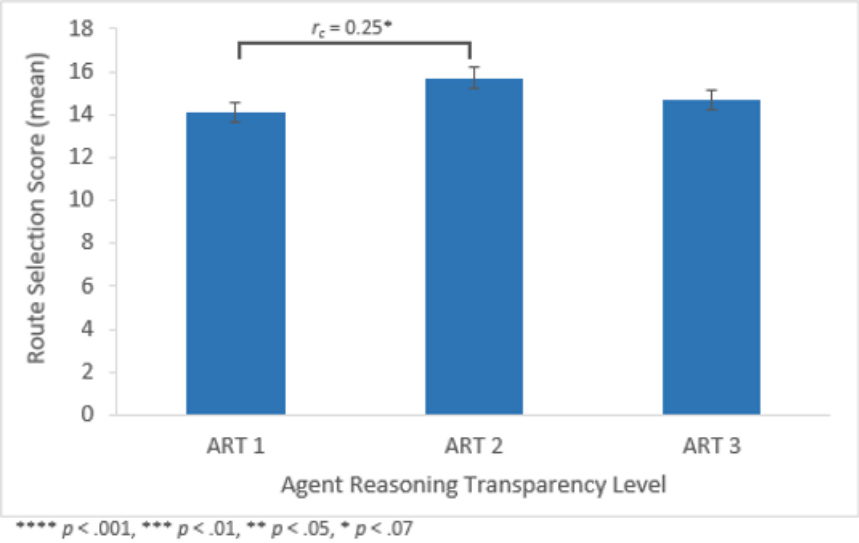

Fig. 7 Average route-selection task score by ART level; bars denote SE

Overall DT in ART2 was slightly shorter than in ART1 or ART3; however, this difference was not significant. Although this result is contrary to what was expected (DT increasing as ART increased), this could provide additional support for

Hypothesis 2, as the slight reduction in DT regardless of the increased amount of information to process could indicate a performance improvement in ART2 over ART1 when considered jointly with the route-selection task performance. The lack of difference between ARTs 2 and 3 for overall DT could indicate the increased access to reasoning had little effect on DT.

Overall DTs for acceptances were compared to those for rejections (of the agent recommendation) using paired t-tests, and there was no significant difference across ART levels. Overall DTs for correct responses were compared to those for incorrect responses using paired t-tests and were found to be significantly shorter, $t(48) = -2.15$, $p = .037$, $d = 0.17$. Within each ART, this difference neared significance only in ART 2, $t(16) = -1.91$, $p = .074$, $d = 0.27$ (see Fig. 8). DTs for correct responses and for incorrect responses were evaluated between ARTs, and there were no significant differences.

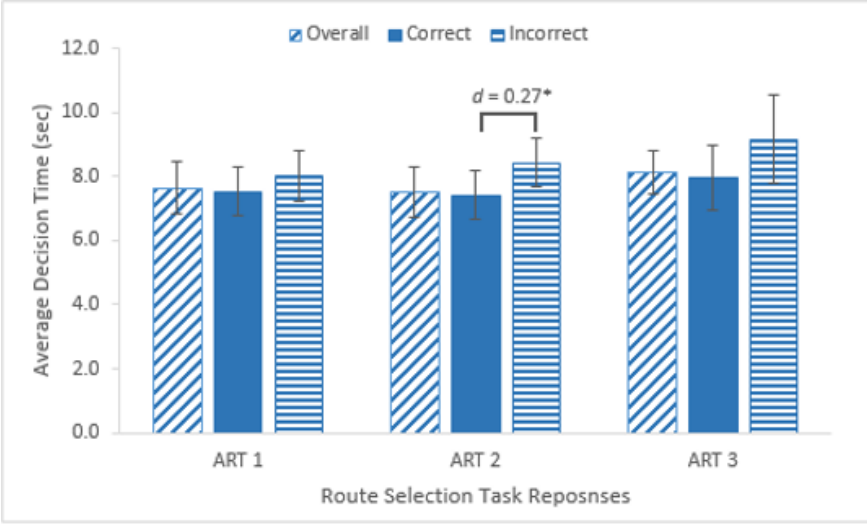

Fig. 8 Comparison of average DTs for correct responses and incorrect responses shown by ART level; bars denote SE

Examining the distribution of scores for the route-selection task, the potential range of scores was 0–18 and the range of participants' scores was 6–18 (see Fig. 9). Of these, 12 participants scored 18/18, 6 of whom were in ART3. Only 2 participants scored less than 50%; the majority scored 67% or higher. Of these scores there appeared to be another break point near 80%, so this was used as a natural delineation for sorting the scores into groups (i.e., 17–15, 14–12, < 12). Participants in ART1 were evenly split between the 17–15 and 14–12 groups. However, there is an interesting difference between these groups for ARTs 2 and 3, in that ART2 participants make up 52% of the 17–15 group while ART3 participants make up 45% of the 14–12 group. This appears to offer additional support for the hypothesis,

as performance in the agent reasoning conditions was better than in the notification-only condition, and performance does appear to be slightly worse in ART3 than in ART2.

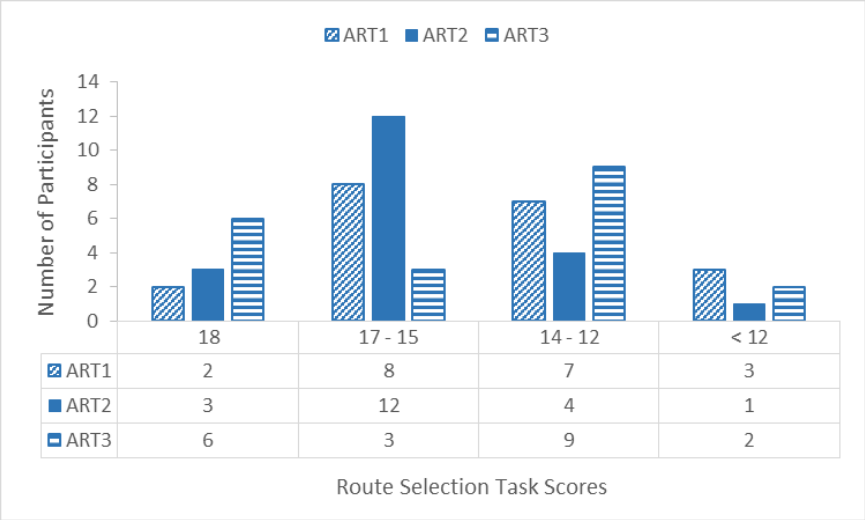

Fig. 9 Distribution of scores for the route-selection task across ART levels

3.4.1.3 Operator-Trust Evaluation

Hypothesis 3: Access to agent reasoning will increase operator trust in the agent, ART1 < ART2, and increased transparency of agent reasoning will decrease operator trust in the agent, ART2 > ART3.

Descriptive statistics for incorrect rejections and the Usability and Trust Survey scores are shown in Table 3.

Table 3 Descriptive statistics for incorrect rejections and Usability and Trust Survey results sorted by ART level

		N	Mean	SD	SE	95% CI for mean
Incorrect rejections	ART1	20	0.85	1.53	0.34	(0.13, 1.57)
	ART2	20	1.10	1.33	0.30	(0.48, 1.72)
	ART3	20	0.75	1.68	0.38	(–0.04, 1.54)
Usability and trust survey	ART1	20	62.75	7.38	1.65	(59.29, 66.21)
	ART2	20	56.25	9.24	2.07	(51.92, 60.58)
	ART3	20	62.50	8.27	1.85	(58.63, 66.37)
Usability responses	ART1	20	46.75	5.33	1.19	(44.26, 49.24)
	ART2	20	40.75	6.60	1.48	(37.66, 43.84)
	ART3	20	45.75	7.03	1.57	(42.46, 49.04)
Trust responses	ART1	20	58.55	8.28	1.85	(54.67, 62.43)
	ART2	20	54.40	10.23	2.29	(49.61, 59.19)
	ART3	20	61.60	11.72	2.62	(56.12, 67.08)

Planned comparisons revealed incorrect rejections were slightly higher in ART2 than in ART1 and ART3, which is contrary to predicted outcomes; however, this difference was not statistically significant (see Fig. 10).

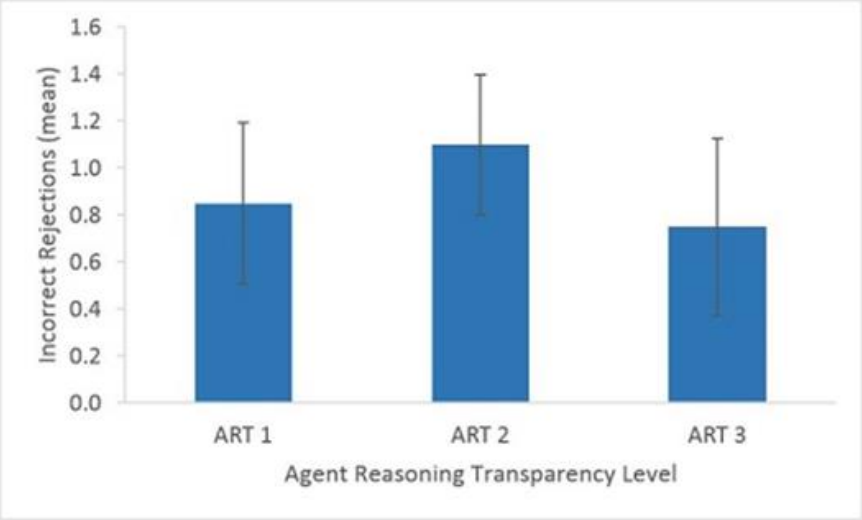

Fig. 10 Average incorrect rejections by ART level; bars denote SE

The DT for responses at the locations where the agent recommendation was correct was evaluated as a potential indicator of operator trust. It was hypothesized that DT would increase as agent reasoning transparency increased, as participants should require additional time to process the extra information. Thus, increased time could indicate more time spent on deliberation, which may imply lower trust (e.g., less complacent behavior). However, reduced DTs for incorrect rejections of the agent recommendation at those locations could be indicative of complacent behavior or greater trust.

Paired t-tests were used to compare differences between DTs for correct acceptances and incorrect rejections within each ART at those locations where the agent recommendation was correct (see Fig. 11). DTs for incorrect rejections were significantly longer than for correct acceptances in ART2, $t(13) = -2.56$, $p = .024$, $d = 0.47$. However, there was no difference between the 2 in ART1 or ART3. This lack of difference between correct and incorrect DTs in ARTs 1 and 3 could indicate a more complacent stance toward critiquing the agent recommendation in those conditions, while participants in ART2 appeared to maintain a more engaged, critical stance.

Fig. 11 Average DT, in seconds, for correct acceptances and incorrect rejections within each ART level; bars denote SE

Examining the distribution of incorrect rejections at those locations where the agent recommendation was correct across ARTs, 33 participants had no incorrect rejections. These were predominately in ARTs 1 and 3, ART2 having half as many perfect scores as the other 2 conditions (see Fig. 12). The range for potential scores for incorrect rejections was 0–12, and the range of participants' scores was 0–6. Twenty-seven participants had at least one incorrect rejection, and these scores were sorted into <50% (score 3 or less) and >50% (score 4 or higher). Half of the participants in ART2 (10) had only one incorrect rejection. Considering perfect scores and one incorrect rejection together, it appears performance between the ARTs was relatively consistent. However, this may also be evidence of more complacent behavior in ARTs 1 and 3, where the agent recommendation was accepted more often, compared to more engaged, critical behavior in ART2, which resulted in occasional errors in judgment and incorrect responses.

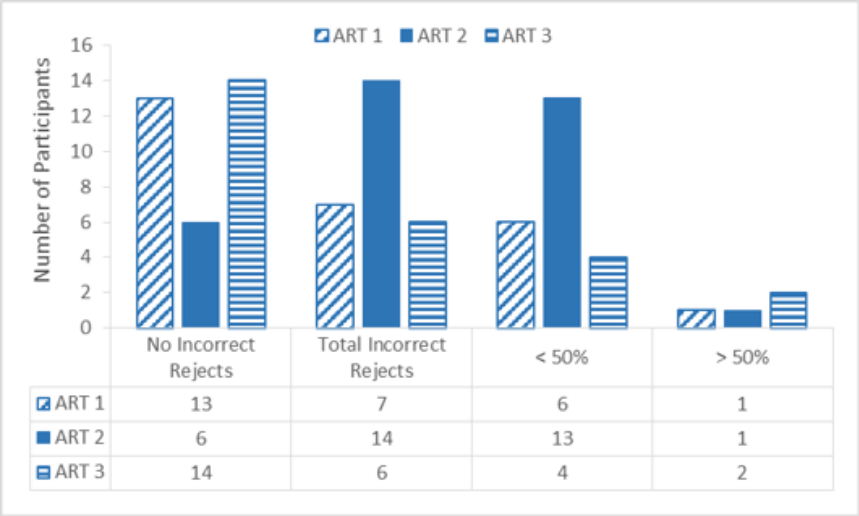

Fig. 12 Distribution of scores for incorrect rejections sorted by ART level

Operator trust was also evaluated using the Usability and Trust Survey. A between-groups ANOVA was conducted to assess the effect of ART on Usability and Trust Survey scores and found a significant effect, $F(2,57) = 3.00$, $p = .057$, $\omega^2 = .06$ (see Fig. 13). Usability and trust scores in ART2 were lower than in either ART1, $t(57) = -1.83$, $p = .073$, $r_c = .24$, or ART3, $t(57) = 2.33$, $p = .023$, $r_c = .29$, which is contrary to the hypothesis. These scores indicate participants trusted the agent more in ARTs 1 and 3 than in ART2. Adding ART reduced perceived usability and trust; however, increased transparency of agent reasoning appeared to improve perceived usability and trust of the agent.

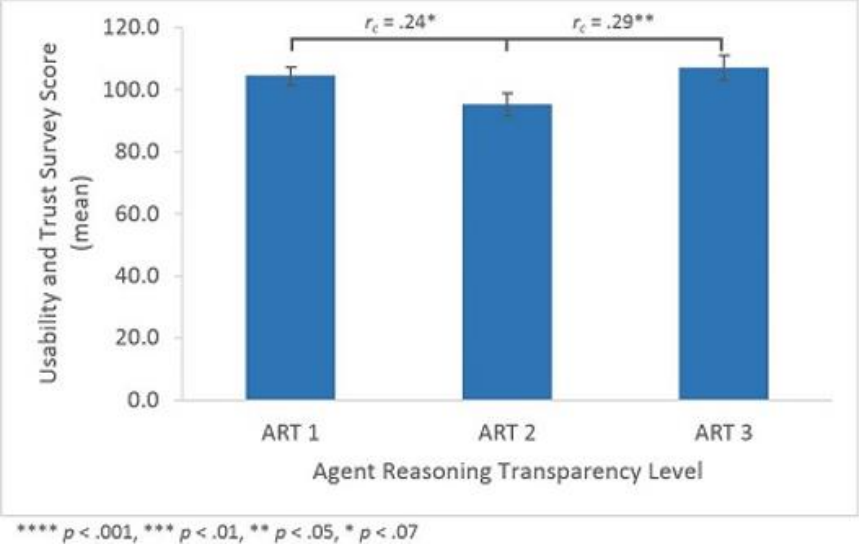

Fig. 13 Average Usability and Trust Survey scores by ART level; bars denote SE

The Usability and Trust Survey is a combination of surveys measuring usability and trust. These individual surveys were also evaluated separately to assess whether the findings were due to mainly operator trust or perceived usability.

PAC scores were found to be significant predictors of trust-survey scores, $R^2 = .078$, $b = .384$, $t(58) = 2.21$, $p = .031$, and usability-survey scores, $R^2 = .084$, $b = .260$, $t(58) = 2.31$, $p = .025$. Participants who scored higher on PAC also scored higher on the trust survey and the usability survey than their counterparts.

There was not a significant overall effect of ART on trust score (see Fig. 14). Planned comparisons revealed trust scores in ART2 were slightly lower than in ART1 and significantly lower than ART3 scores, $t(57) = 2.24$, $p = .029$, $r_c = .28$. These findings do not support the hypothesis, as ART2 had the lowest trust scores while ART3 had the highest.

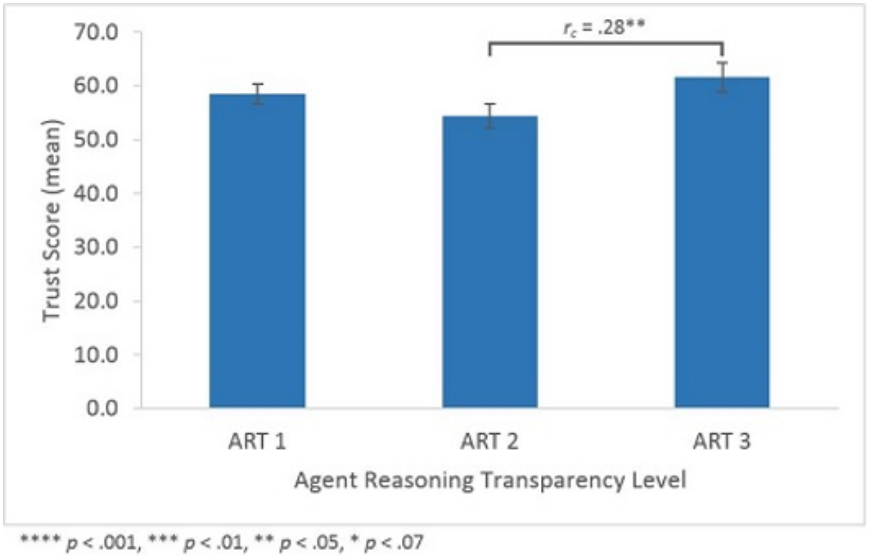

Fig. 14 Average trust scores by ART level; bars denote SE

There was a significant effect of ART on usability scores, $F(2,57) = 5.11$, $p = .009$, $\omega^2 = .12$, (see Fig. 15). Planned comparisons show usability scores in ART2 were significantly lower than those in either ART1, $t(57) = –2.98$, $p = .004$, $r_c = .37$, or ART3, $t(57) = 2.49$, $p = .049$, $r_c = .31$. Overall, usability scores were significantly lower when agent reasoning was present than when it was not, $t(57) = –2.01$, $p = .049$, $r_c = .26$. While access to agent reasoning appeared to decrease perceived usability of the agent, increased access to agent reasoning appeared to improve perceived usability of the agent.

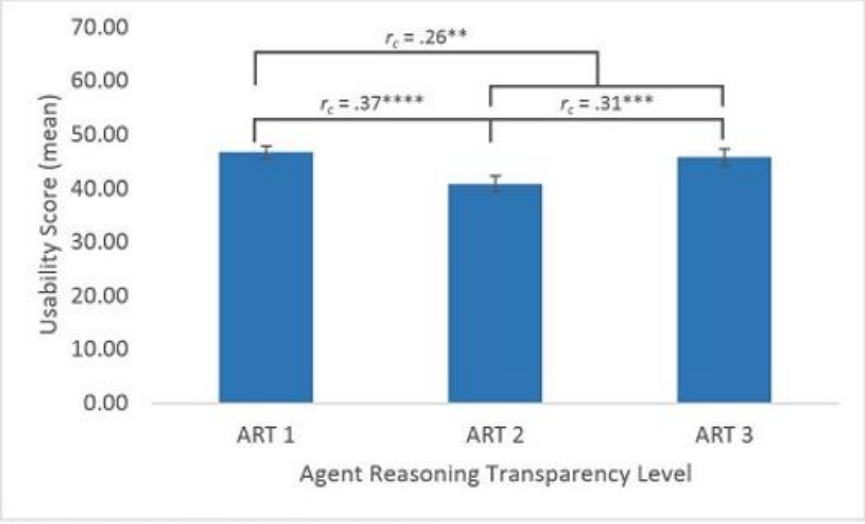

Fig. 15 Average usability scores by ART level; bars denote SE

3.4.2 Workload

Hypothesis 4: Access to agent reasoning will increase operator workload, ART1 < ART2; and, increased transparency of agent reasoning will increase operator workload, ART2 < ART3. When agent reasoning is not available, workload will be lower than when agent reasoning is present, ART1 < ART2+3.

SOT scores were found to be significant predictors of global NASA-TLX scores, R^2 = .10, b = 0.57, $t(58)$ = 2.52, p = .015. Participants who scored higher on the SOT, indicating a lesser ability to orient and navigate in their environment, also scored higher on the global NASA-TLX than their counterparts.

Planned contrasts revealed there was no overall difference in participant workload when agent reasoning was available compared to the no-reasoning condition (see Fig. 16). Participants in ART1 reported lower workload than those in ART2 and workload was higher in ART2 than in ART3. Although workload scores decreased in ART3, there was no significant difference between ARTs.

Fig. 16 Average global NASA-TLX scores by ART level; bars denote SE

Cognitive workload was also evaluated using several ocular indices. Descriptive statistics are shown in Table 4. Not all participants had complete eye-measurement data, so this N was reduced (n = 12 for each ART). Eye-tracking data were evaluated using the same planned comparisons as the subjective workload measure.

Table 4 Descriptive statistics for eye-tracking measures by ART condition

		N	Mean	SD	SE	95% CI for mean
Pupil diameter (mm)	ART1	12	3.71	0.32	0.09	(3.50, 3.91)
	ART2	12	3.56	0.32	0.09	(3.36, 3.76)
	ART3	12	3.46	0.39	0.11	(3.21, 3.70)
Fixation duration (ms)	ART1	12	264.54	42.16	12.17	(237.75, 291.33)
	ART2	12	288.53	42.21	12.18	(261.71, 315.35)
	ART3	12	265.71	25.23	7.28	(249.68, 281.74)
Fixation count	ART1	12	4895.18	513.60	148.26	(4568.85, 5221.51)
	ART2	12	4809.97	875.08	252.61	(4253.97, 5365.97)
	ART3	12	5076.82	421.63	121.72	(4808.93, 5344.71)

ART had no significant effect on participants' pupil diameter, fixation count, or fixation duration. Planned comparisons did not reach statistical significance; as such, there was no indication of any difference in cognitive workload between the 3 ART conditions.

The NASA-TLX global score is a composite score made up of 6 factors. Examining these factors separately, correlations between factors were low or nonexistent. Individual evaluations of each factor across ART were made by one-way ANOVAs using Bonferroni correction, $\alpha = .008$ (see Table 5).

Table 5 Evaluation of NASA-TLX workload factors across ART levels; MD = mental demand, PhyD = physical demand, TD = temporal demand, Perf = performance, Frust = frustration level.

	Mean (SD)			One-way ANOVA (α = .008)		Planned comparisons (Cohen's *d*)		
	ART1	**ART2**	**ART3**	***F*(2,57)**	**ω^2**	**ART1–2**	**ART2–3**	**ART1–2+3**
MD	74.75 (20.10)	79.75 (13.33)	72.50 (16.34)	0.97	.00	0.25	0.36	0.08
PhyD	14.25 (12.06)	11.25 (6.46)	17.75 (13.91)	1.95	.02	0.36	0.73*	0.03
TD	55.50 (24.49)	61.75 (19.08)	45.75 (19.49)	2.90*	.06	0.25	0.63**	0.10
Perf	50.00 (18.92)	46.25 (25.23)	57.00 (20.16)	1.28	.01	0.15	0.42	0.07
Effort	76.25 (15.29)	71.25 (18.13)	72.25 (15.26)	0.53	.02	0.26	0.05	0.27
Frust	49.25 (24.40)	48.50 (27.00)	34.00 (17.29)	3.49**	.05	0.03	0.71**	0.41

**** $p < .001$; *** $p < .01$; ** $p < .05$; * $p < .07$

MD was the factor contributing the most to workload, and ART2 elicited greater MD than ARTs 1 or 3 (see Fig. 17). However, the effect size for the difference between ARTs was small, indicating there is little to no difference in MD. PhyD contributed the least to overall workload. PhyD scores were significantly higher in ART 3 than in ART2.

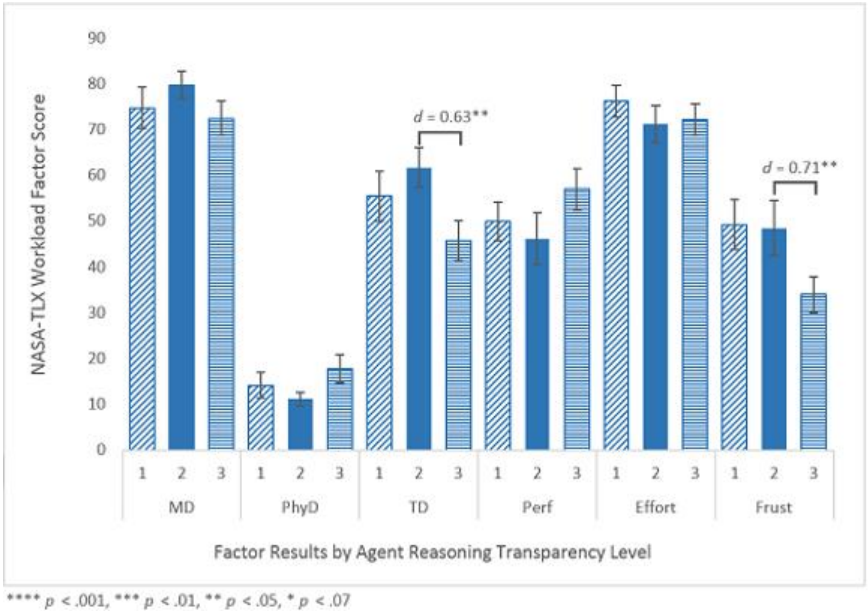

Fig. 17 NASA-TLX workload-factor average scores by ART level; bars denote SE

Effort decreased when access to agent reasoning was available; however the effect sizes were small. TD and Frustration scores were consistent between ARTs 1 and 2, but dropped off in ART3, indicating the additional access to agent reasoning may have alleviated some of the pressure on participants in these ARTs. Performance-factor scores are inverted, with lower scores indicating greater satisfaction. Performance-factor scores indicate participants in ARTs 1 and 2 were similarly satisfied with their performance, but those in ART3 were less satisfied with their performance.

SOT scores correlated significantly with TD (r = .36, p = .005) and Effort (r = .31, p = .015) scores, but no other NASA-TLX factors. Participants with high SOT scores, which implies low spatial- orientation ability, reported greater TD in both ART2 (d = 0.82) and ART3 (d = 0.74) than their low-SOT-scoring counterparts. High-SOT-score participants also reported greater Effort in ART1 (d = 1.09) and ART3 (d = 1.37) than their low-SOT counterparts. However, there was little difference in Effort due to SOT in ART2 (d = 0.24).

3.4.3 SA

Hypothesis 5: Access to agent reasoning will improve SA scores, and increased transparency of agent reasoning will improve SA1 and SA2 scores but will reduce SA3 scores:

- SA1: ART1 < ART2, ART2 < ART3;
- SA2: ART1 < ART2, ART2 < ART3;
- SA3: ART1 < ART2, ART2 > ART3.

Descriptive statistics for SA scores are shown in Table 6.

Table 6 Descriptive statistics for SA scores by ART level

		N	Mean	SD	SE	95% CI for mean	Min	Max
SA1	ART1	20	1.35	4.93	1.10	(0.96, 3.66)	–8	12
	ART2	20	0.10	5.86	1.31	(–2.64, 2.84)	–10	12
	ART3	20	3.85	3.65	0.82	(2.14, 5.56)	–5	9
SA2	ART1	20	11.40	3.89	0.87	(9.58, 13.22)	5	18
	ART2	20	13.15	3.70	0.83	(11.42, 14.88)	5	18
	ART3	20	11.20	5.42	1.21	(8.67, 13.73)	1	18
SA3	ART1	20	1.90	8.56	1.91	(–2.11, 5.91)	–12	14
	ART2	20	3.85	8.98	2.01	(–0.35, 8.05)	–11	16
	ART3	20	6.15	8.19	1.83	(2.32, 9.98)	–10	17

Spatial-visualization scores were found to be significant predictors of SA1 scores, R^2 = .13, b = 9.76, t(58) = 2.94, p = .005. Participants who scored higher in SV, indicating a greater ability to manipulate objects mentally in 3-D space, also scored higher on SA1 than their counterparts.

SA Level 1 (perception of environment) scores indicated a significant effect of ART, F(2,57) = 3.04, p = .056, ω^2 = .06 (see Fig. 18). Participants in ART2 had lower SA1 scores than those in ART1, but not significant, and significantly lower SA1 scores than those in ART3, t(57) = 2.42, p = .019, r_c = .31. There were no meaningful differences in SA1 scores between ART2 and ART1; however, SA1 scores were greatest in ART3, partially supporting the hypothesis that increased transparency of agent reasoning will lead to improved SA1 scores.

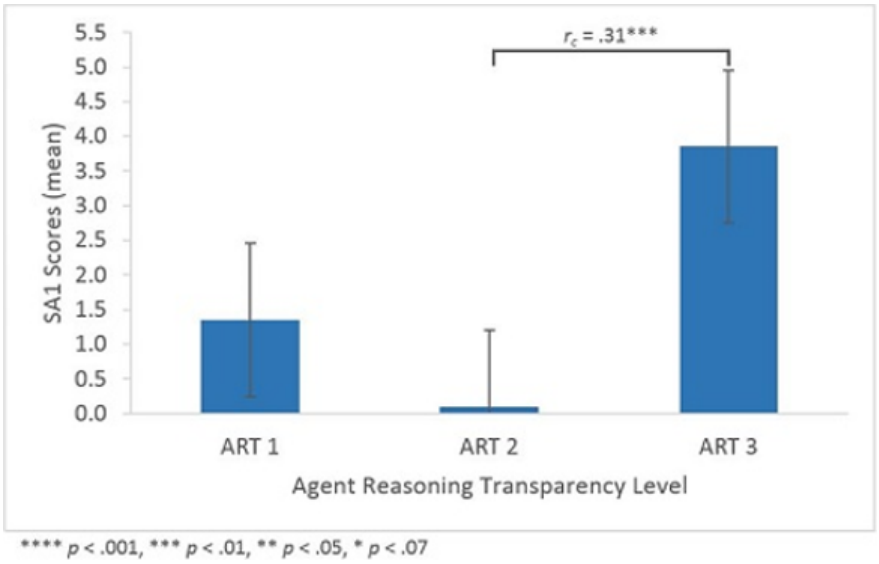

Fig. 18 Average SA1 scores by ART level; bars denote SE

SV scores were found to be significant predictors of SA2 scores, R^2 = .11, b = 7.71, t(58) = 2.62, p = .011. Participants who scored higher in SV, indicating a greater ability to manipulate objects mentally in 3-D space, also scored higher on SA2 than their counterparts.

SA2 (comprehension) scores indicated no significant effect of ART. SA2 scores were evaluated regardless of route selection and along the ground-truth route and no significant difference in results was found. The hypothesis was not supported, in that access to agent reasoning appeared to have no effect on SA2 scores.

SA3 (projection) scores indicated a marginally significant difference between ARTs, F(2,36.7) = 2.92, p = .067, ω^2 = .04 (see Fig. 19). There was also a significant linear trend, F(1,36.7) = 4.35, p = .041, ω^2 = .05, indicating SA3 scores increased as ART increased. SA3 was evaluated regardless of route selection and

along the ground-truth route only, and no significant difference in results was found. The hypotheses were not supported. Although SA3 scores in ART2 were greater than those in ART1, as predicted, this difference did not reach significance. SA3 scores in ART3 were predicted to be lower than those in ART2; instead, they increased as access to agent reasoning increased. While the difference between groups did not reach significance, the significant linear trend indicates increased access to agent reasoning does help participants project future status.

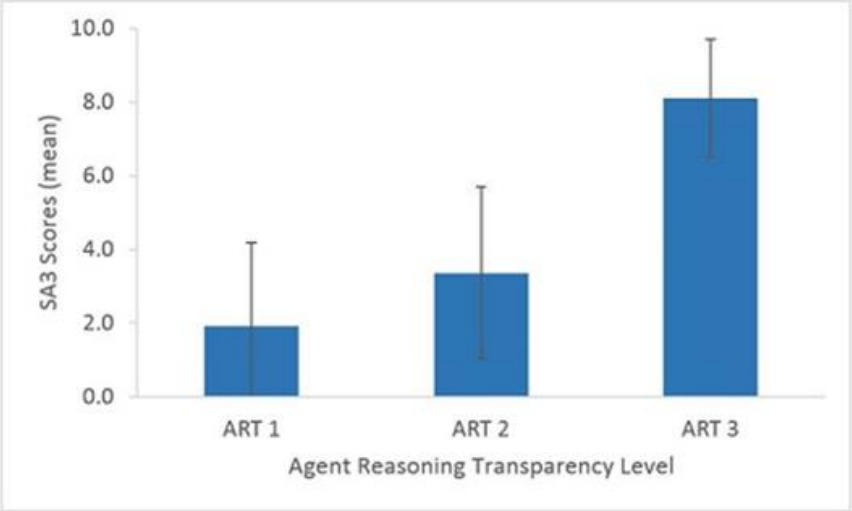

Fig. 19 Average SA3 score by ART level; bars denote SE

3.4.4 Target-Detection Task Performance

Hypothesis 6*:* Access to agent reasoning will reduce the number of targets detected and the number of FAs, ART1 > ART2, and increased transparency of agent reasoning will again result in fewer targets detected and fewer FAs, ART2 > ART3.

Descriptive statistics for Target Detection measures are shown in Table 7.

Table 7 Descriptive statistics for target detection task measures by ART level; *d′* = sensitivity, β = selection bias

		N	Mean	SD	SE	95% CI for mean	Min	Max
Targets detected (count)	ART1	20	44.45	10.10	2.26	(39.72, 49.18)	30	69
	ART2	20	45.05	13.64	3.05	(38.66, 51.44)	11	65
	ART3	20	44.75	10.19	2.28	(39.98, 49.52)	29	65
FAs (count)	ART1	20	20.80	6.25	1.40	(17.87, 23.73)	10	33
	ART2	20	16.35	5.29	1.18	(13.87, 18.83)	7	27
	ART3	20	17.30	7.53	1.68	(13.78, 20.82)	8	32
d′	ART1	20	2.20	0.32	0.07	(2.05, 2.35)	1.73	2.94
	ART2	20	2.31	0.44	0.10	(2.11, 2.52)	1.40	3.19
	ART3	20	2.29	0.38	0.09	(2.11, 2.46)	1.57	2.94
β	ART1	20	2.42	0.28	0.06	(2.29, 2.56)	2.00	3.06
	ART2	20	2.60	0.33	0.07	(2.45, 2.76)	1.90	3.21
	ART3	20	2.60	0.37	0.08	(2.43, 2.78)	1.91	3.23

SV scores were found to be significant predictors of total number of Targets Detected, $R^2 = .07$, $b = 15.71$, $t(58) = 2.06$, $p = .044$. Participants who scored higher in SV, indicating a greater ability to mentally manipulate objects in 3-D space, also detected more targets in their environment than their counterparts.

There was no significant effect of ART on the number of targets detected. The number of targets detected was slightly greater in ART2 than in ART1 or ART3; however, these differences were not significant.

SV scores ($r = –.39$, $p = .001$) and WMC scores ($r = –.31$, $p = .009$) correlated significantly with the total number of FAs reported. SV scores were found to be significant predictors of FAs, $R^2 = .15$, $b = –14.55$, $t(57) = –2.80$, $p = .007$, while WMC scores were shown to be marginal predictors of number of FAs reported, $R^2 = .05$, $b = –0.16$, $t(57) = \text{M} –1.87$, $p = .067$. Participants who scored higher in SV, as well as those who scored higher on WMC measures, reported fewer FAs than their counterparts.

The number of FAs was lower in ART2 than in ART1, $t(57) = –2.19$, $p = .033$, $r_c = .28$; however, there was little to no difference in number of reported FAs between ARTs 2 and 3 (see Fig. 20). Thus, the hypothesis was partially supported, as the addition of agent reasoning transparency did result in fewer FAs; however, the increased transparency did not further reduce FAs.

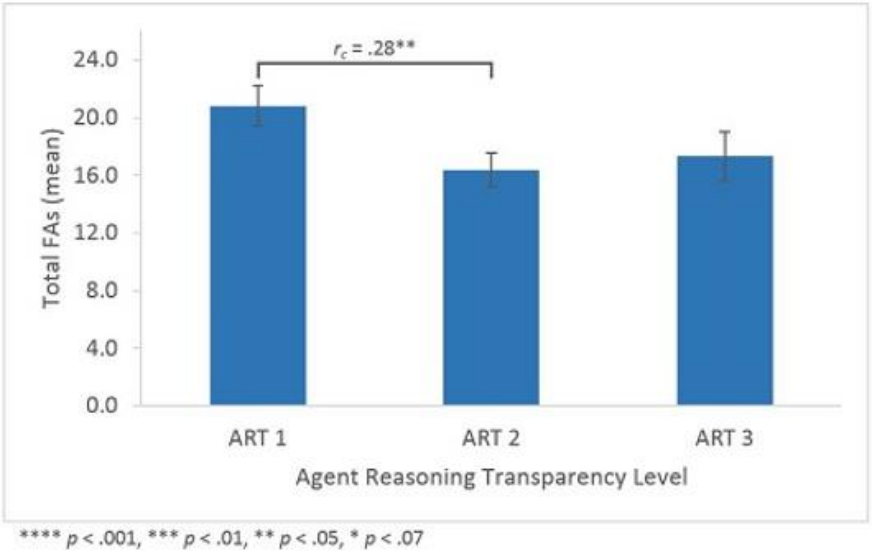

Fig. 20 Average number of FAs by ART level; bars denote SE

Results of the target-detection task were also evaluated using SDT to determine if there were differences in *d'* or β between the 3 ARTs. There was no significant effect of ART on *d'* (see Fig. 21). Participants were slightly more sensitive to targets in ART2 than in ART1 or ART3; however, these differences did not achieve statistical significance.

Evaluating β across ART, there was no significant effect of ART on β scores (see Fig. 21). Beta scores were slightly lower in ART1 than in ART2, $t(57) = 1.71$, $p = .094$, $r_c = .22$, and there was no difference in β between ART2 and ART3. This could indicate the presence of agent reasoning allowed the participants to use a stricter selection criterion than in the no-reasoning condition, but increasing the amount of agent reasoning did not have any further effect on participants' selection criteria. The slightly more-lenient selection criteria in ART1 could be why there were more FAs reported in ART1 than in either ARTs 2 or 3.

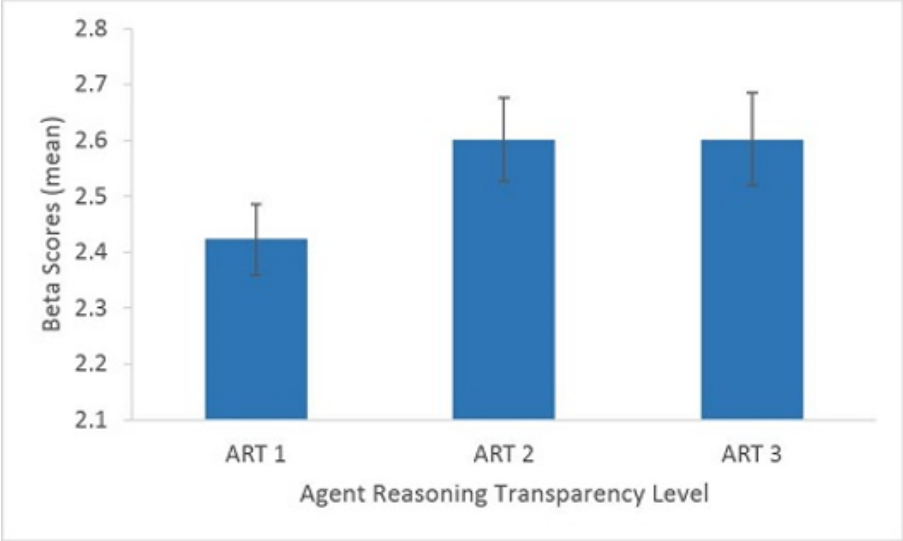

Fig. 21 Average beta (β) scores by ART level; bars denote SE

3.4.5 Individual Differences Evaluations

3.4.5.1 Complacency Potential

CP was evaluated via the CPRS scores. The effect of CP on several measures of interest across ART level was evaluated via 2-way between-groups ANOVAs, $\alpha = .05$. Post hoc t-tests within each ART compared performance differences between high/low group memberships. Descriptive statistics for CP, as measured using the CPRS, are shown in Tables 8 and 9.

Table 8 Descriptive statistics for CPRS scores by ART level

							Mdn split count	
Group	**N**	**Min**	**Max**	**Mdn**	**Mean**	**SD**	**Hi**	**Lo**
Overall	60	28	49	39.50	39.90	4.90	30	30
ART1	20	28	46	38.00	38.50	4.90	8	12
ART2	20	29	48	41.50	40.90	5.00	10	10
ART3	20	33	49	41.00	40.30	4.60	12	8

Table 9 Descriptive statistics for high/low CPRS scores by ART level

		N	**Mean**	**SD**	**SE**	**95% CI for mean**
ART1	Low CPRS	12	35.33	3.11	0.90	(33.35, 37.31)
	High CPRS	8	43.25	2.55	0.90	(41.12, 45.38)
ART2	Low CPRS	10	36.80	3.50	1.11	(34.20, 38.20)
	High CPRS	10	45.10	1.37	0.43	(44.12, 46.08)
ART3	Low CPRS	8	35.50	1.77	0.63	(34.02, 36.98)
	High CPRS	12	43.50	2.68	0.77	(41.80, 45.20)

Hypothesis 7: High-CPRS individuals will have fewer correct rejections on the route-selection task than low-CPRS individuals.

A 2-way, between-groups ANOVA revealed no significant interaction between CPRS and ART on the number of correct rejections in the route-planning task nor any significant main effect of CPRS on the number of correct rejections in the route-planning task.

Hypothesis 8: High-CPRS individuals will have higher scores on the Usability and Trust Survey than low-CPRS individuals.

A 2-way, between-groups ANOVA revealed no significant interaction between CPRS and ART on Usability and Trust Survey scores nor any significant main effect of CPRS on usability scores.

Hypothesis 9: High-CPRS individuals will have lower SA scores than low-CPRS individuals.

A 2-way, between-groups ANOVA revealed no significant interaction between CPRS and ART on SA scores nor any significant main effect of CPRS on SA scores.

3.4.5.2 Spatial Ability (SOT and SV) and Perceived Attentional Control

Hypothesis 10: Individual differences, such as SpA and PAC, will have differential effects on the participant's performance on the route-selection task and their ability to maintain SA.

The effects of ID factors and ART level on route-selection performance were evaluated via 2-way, between-groups ANOVAs, $\alpha = .05$. When Levene's Test of Equality of Error Variance was significant, the evaluation was repeated at $\alpha = .01$. Post hoc t-tests within each ART compared performance differences between high- and low-group memberships for each ID factor. Descriptive statistics for SOT, SV, and PAC are shown in Tables 10 and 11.

Table 10 Descriptive statistics for SOT, SV, and PAC by ART level

								Mdn split count	
	Group	**N**	**Min**	**Max**	**Mdn**	**Mean**	**SD**	**Hi**	**Lo**
SOT	Overall	60	3.97	29.54	12.72	13.59	7.28	30	30
	ART1	20	5.70	22.00	14.06	13.27	5.20	8	12
	ART2	20	4.12	29.00	10.10	13.35	7.98	11	9
	ART3	20	3.97	29.54	11.22	14.15	8.56	11	9
SV	Overall	60	0.19	0.95	0.50	0.53	0.19	35	25
	ART1	20	0.19	0.93	0.54	0.54	0.19	12	8
	ART2	20	0.21	0.86	0.54	0.52	0.20	13	7
	ART3	20	0.21	0.95	0.49	0.52	0.18	10	10
PAC	Overall	60	41.0	74.0	61.00	60.50	7.50	32	28
	ART1	20	46.0	74.0	65.50	63.00	8.00	13	7
	ART2	20	47.0	69.0	60.50	60.10	6.00	10	10
	ART3	20	41.0	74.0	60.00	58.50	8.20	9	11

Table 11 Descriptive statistics for SOT, SV, and PAC by ART level, sorted by high/low group membership

			N	**Mean**	**SD**	**SE**	**95% CI for mean**
SOT	ART1	Low	12	16.88	2.95	0.85	(13.11, 22.00)
		High	8	7.86	1.98	0.70	(5.70, 11.55)
	ART2	Low	9	20.90	5.28	1.76	(14.64, 29.00)
		High	11	7.16	2.32	0.70	(4.12, 10.43)
	ART3	Low	9	21.93	6.47	2.16	(12.72, 29.54)
		High	11	7.78	2.56	0.77	(3.97, 12.71)
SV	ART1	Low	8	0.36	0.09	0.03	(0.19, 0.45)
		High	12	0.66	0.14	0.04	(0.50, 0.93)
	ART2	Low	7	0.30	0.11	0.04	(0.21, 0.48)
		High	13	0.64	0.12	0.03	(0.50, 0.86)
	ART3	Low	10	0.39	0.08	0.03	(0.21, 0.48)
		High	10	0.66	0.14	0.04	(0.50, 0.95)
PAC	ART1	Low	7	53.57	4.24	1.60	(46.0, 60.0)
		High	13	68.08	3.62	1.00	(62.0, 74.0)
	ART2	Low	10	55.50	4.43	1.40	(47.0, 60.0)
		High	10	64.70	2.95	0.93	(61.0, 69.0)
	ART3	Low	11	53.18	6.84	2.06	(41.0, 60.0)
		High	9	64.89	3.98	1.33	(61.0, 74.0)

3.4.5.2.1 Route-Selection Task Evaluation

SOT was not found to be a significant predictor of performance on the route-selection task independent of ART. A 2-way, between-groups ANOVA revealed no significant interaction between SOT and ART on route-selection scores nor any significant main effect of SOT on route-selection scores.

SV was found to be a significant predictor of performance on the route-selection task independent of ART level, $R^2 = .10$, $\beta = .31$, $t(58) = 2.52$, $p = .015$. A 2-way, between-groups ANOVA, $\alpha = .01$, revealed no significant interaction between SV and ART on route-selection scores; however, there was a significant main effect of SV on route-selection scores, $F(1,54) = 4.31$, $p = .043$, $\eta_p^2 = .07$ (see Fig. 22). Post hoc comparisons between high- and low-SV groups within each ART level show that high-SV and low-SV individuals had similar route-selection scores in ART1 and ART3. However, in ART2 the high-SV individuals had higher route-selection scores, $t(18) = -3.08$, $p = .017$, $d = 1.59$, indicating they benefited from the access to agent reasoning more than their low-SV counterparts.

Fig. 22 Average route-selection scores by high/low SV group membership, sorted by ART level; bars denote SE

A 2-way, between-groups ANOVA revealed no significant interaction between PAC and ART on route-selection scores nor any significant main effect of SOT on route-selection scores.

3.4.5.2.2 SA1 Evaluation

A 2-way, between-groups ANOVA revealed no significant interaction between SOT and ART on SA1 scores nor any significant main effect of SOT on SA1 scores.

A 2-way, between-groups ANOVA revealed no significant interaction between SV and ART on SA1 scores; however, there was a significant main effect of SV on SA1 scores, $F(1,54) = 14.62$, $p < .001$, $\eta_p^2 = .21$ (see Fig. 23). High-SV individuals had higher SA1 scores in all ARTs—ART1, $t(18) = -1.73$, $p = .101$, $d = 0.81$; ART2, $t(18) = -2.39$, $p = .028$, $d = 1.09$; and ART3, $t(18) = -2.79$, $p = .012$, $d = 1.25$—than their low-SV counterparts; however, this difference was not significant in ART1.

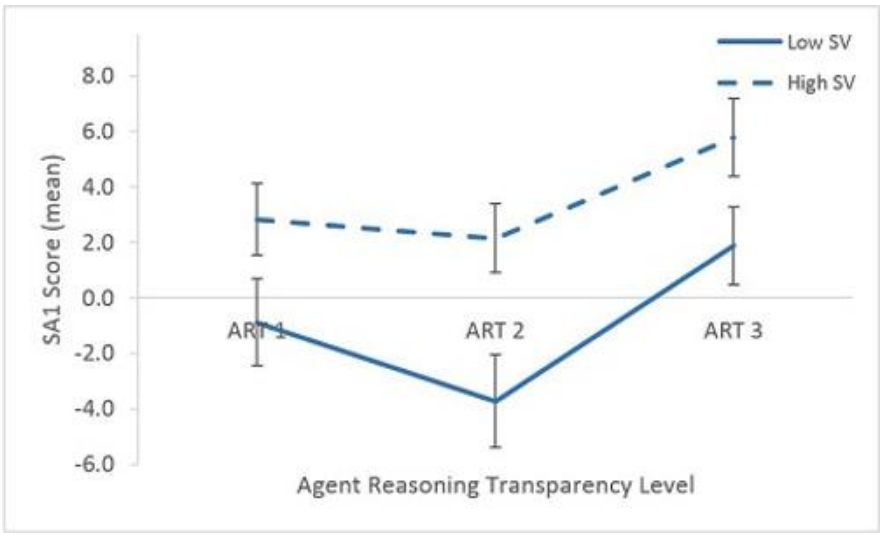

Fig. 23 Average SA1 scores by SV high/low group membership, sorted by ART level; bars denote SE

A 2-way, between-groups ANOVA revealed no significant interaction between PAC and ART on SA1 scores nor any significant main effect of PAC on SA1 scores.

3.4.5.2.3 SA2 Evaluation

Two-way, between-groups ANOVAs revealed no significant ART interaction with SOT, SV, or PAC on SA2 scores nor any significant main effect of SOT, SV, or PAC on SA2 scores.

3.4.5.2.4 SA3 Evaluation

A 2-way, between-groups ANOVA revealed no significant interaction between SOT and ART on SA3 scores nor any significant main effect of SOT on SA3 scores.

A 2-way, between-groups ANOVA revealed no significant interaction between SV and ART on SA3 scores; however, there was a significant main effect of SV on SA3 scores, $F(1,54) = 6.73$, $p = .012$, $\eta_p^2 = .11$ (see Fig. 24). High-SV individuals had higher SA3 scores in all ARTs than their low-SV counterparts, although this difference only neared significance in ART2, $t(18) = –1.89$, $p = .075$, $d = 0.85$.

A 2-way, between-groups ANOVA revealed no significant interaction between PAC and ART on SA3 scores and no significant main effect of PAC on SA3 scores.

Fig. 24 Average SA3 scores by SV high/low membership sorted by ART level; bars denote SE

3.4.5.3 WMC

Hypothesis 11: High-WMC individuals will have more correct rejections and higher SA2 and SA3 scores than low-WMC individuals.

The effects of Working Memory Capacity and ART level were evaluated via 2-way, between-groups ANOVAs, $\alpha = .05$. Post hoc t-tests within each ART compared performance differences between high/low group memberships. Descriptive statistics for WMC, as measured using the RSPAN test, are shown in Tables 12 and 13.

Table 12 Descriptive statistics for WMC by ART level

								Mdn split count	
	Group	**N**	**Min**	**Max**	**Mdn**	**Mean**	**SD**	**Hi**	**Lo**
WMC	Overall	60	5.0	51.0	32.50	31.30	11.10	30	30
	ART1	20	8.0	51.0	30.50	30.90	10.98	9	11
	ART2	20	8.0	49.0	36.00	33.85	9.95	13	7
	ART3	20	5.0	51.0	28.50	29.15	12.39	8	12

Table 13 Descriptive statistics for WMC by ART level, sorted by high/low group membership

			N	**Mean**	**SD**	**SE**	**95% CI for mean**
WMC	ART1	Low	11	22.64	6.36	1.92	(18.36, 26.91)
		High	9	41.00	5.22	1.74	(36.99, 45.01)
	ART2	Low	7	23.29	7.85	2.97	(16.03, 30.54)
		High	13	39.54	5.09	1.41	(36.46, 42.62)
	ART3	Low	12	20.92	7.59	2.19	(16.10, 25.74)
		High	8	41.50	5.98	2.11	(36.50, 46.50)

3.4.5.3.1 Correct Rejections

A 2-way, between-groups ANOVA revealed no significant interaction between WMC and ART on correct-rejection scores nor any significant main effect of WMC on correct-rejection scores.

3.4.5.3.2 SA scores

A 2-way, between-groups ANOVA revealed no significant interaction between WMC and ART on SA scores nor any significant main effect of WMC on SA scores.

3.5 Discussion

Our primary goal was to examine how the transparency of an intelligent agent's reasoning in a low-information environment affected complacent behavior in a route-selection task. Participants supervised a 3-vehicle convoy as it traversed a simulated environment and rerouted the convoy when needed with the assistance of an intelligent agent, RL. Information regarding potential events along the preplanned route, together with communications from a commander confirming either the presence or absence of activity in the area, were provided to all participants. They did not receive any information about the suggested alternate route. However, they were instructed that the proposed path was at least as safe as their original route. When the convoy approached a potentially unsafe area, the intelligent agent would recommend rerouting the convoy. The agent recommendations were correct 66% of the time. The participant was required to recognize and correctly reject any incorrect suggestions. The secondary goal of this study was to examine how differing levels of agent transparency affected main-task and secondary-task performance, response time, workload, SA, trust, and system usability along with implications of ID factors such as spatial ability, WMC, PAC, and CP.

Each participant was assigned to a specific level of ART. The reasoning was provided as to why the agent was making the recommendation and this differed among these levels. ART1 provided no reasoning information; RL notified that a change was recommended without explanation. The type of information the agent supplied varied slightly between ARTs 2 and 3. In ART2 the agent reasoning was a simple statement of fact (e.g., Recommend revise convoy route due to Potential IED [improvised explosive device]). In ART3 an additional piece of information was added that conveyed how long ago the agent had received the information (time of report: TOR) leading to its recommendation (e.g., Recommend revise convoy route due to Potential IED, TOR: 1 [hr]). This additional information did not convey any confidence level or uncertainty, but was designed to encourage the operator to actively evaluate the quality of the information rather than simply respond.

Therefore, not only was access to agent reasoning examined, but the impact of the type of information the agent supplied was examined as well.

Complacent behavior was examined via primary (route-selection) task response in the form of automation bias. Automation bias was quantified as incorrect acceptances of the agent recommendation, an objective measure of errors of commission (Parasuraman et al. 2000). As predicted, access to agent reasoning reduced these incorrect accepts, and increased access to agent reasoning increased incorrect accepts. Complacent behavior was greatest when no agent reasoning was available. When the amount of agent reasoning was increased to its highest level, complacent behavior increased to nearly the same level as in the no-reasoning condition. This pattern of results indicated that while access to agent reasoning in a decision-supporting agent can counter automation bias, too much information resulted in an OOTL situation and increased complacent behavior. Similar to previous findings (Mercado et. al. 2015) access to agent reasoning did not increase response time. In fact, decision times were reduced in the agent reasoning conditions, even though the agent messages in the reasoning conditions were slightly longer than in the no-reasoning condition and required slightly more time to process. Similar studies have suggested that a reduction in accuracy with consistent response times could be attributed to a speed–accuracy trade-off (Wickens et al. 2015). However, the present findings indicated that may not be the case. Initially, there was an increase in accuracy with no accompanying increase in response time (hence, no trade-off). What appears to be more likely is that not only does the access to agent reasoning assist the operator in determining the correct course of action, but the type of information the operator receives also influences their behavior.

In all conditions, the participant received all information needed to correctly route the convoy without the agent's suggestion. In the no-reasoning condition, the participants were less likely to override the agent suggestion, demonstrating a clear bias for the agent suggestion. With a moderate amount of information regarding the agent reasoning, the participants were more confident in overriding erroneous suggestions. In the highest reasoning condition, participants were also given information regarding when the agent had received the information; while this information did not imply any confidence or uncertainty rating, such additional information appeared to create ambiguity for the participant. This encouraged them to defer to the agent's suggestion.

Performance on the route-selection task was evaluated via correct rejections and acceptances of the agent suggestion. An increased number of correct acceptances and rejections, as well as reduced response times, were all indicative of improved performance. Route-selection performance was anticipated as improving with

access to agent reasoning and then declining as access to agent reasoning increased. This hypothesis was partially supported. Performance did improve when access to agent reasoning was provided. Increased transparency of agent reasoning did result in a subsequent decline in scores; however, the small–medium-effect size indicated these results are not strong evidence in support of the latter demand of the hypothesis. SV was predictive of performance on the route-selection task. Individuals with high SV scores outperformed their low-SV counterparts on the route-selection task in ART2. This demonstrated their advantage in the agent reasoning information supplied in this condition. However, this advantage was lost when additional reasoning in ART3 was supplied.

Workload was evaluated using the NASA-TLX and several ocular indices shown to be informative as to cognitive workload, and was hypothesized to increase as agent reasoning transparency increased. Global NASA-TLX scores and pupil diameter decreased slightly, but not significantly, as ART increased, indicating overall cognitive workload decreased as ART increased. This contradicts our stated hypothesis. Similar to Mercado et al. (2015), access to agent reasoning did not increase overall workload, as assessed via global NASA-TLX scores. However, Fixation Count and Fixation Duration did not cohere with the PDia results. FC did not differ significantly between the 3 ARTs. FD was slightly longer in ART2 than in ARTs 1 or 3. Reviewing the NASA-TLX-factor scores yields interesting insights. Participants reported higher satisfaction to queries about their performance (i.e., "How successful do you think you were in accomplishing the goals of the task set by the experimenter? How satisfied were you with your performance in accomplishing these goals?") in ART2. Considered alongside the FD findings, this may be indicative of their level of engagement in that condition. The ratings for NASA-TLX effort (i.e., "How hard did you have to work to accomplish your level of performance?") increased as ART increased. This does support our original hypothesis. The ratings for factor Temporal Demand (i.e., "How much time pressure did you feel due to the rate or pace at which the task or tasks elements occurred? Was the pace slow and leisurely or rapid and frantic?") were greater in ARTs 1 and 2 than in ART3. However, when also considering the low FD in ART3, the reduced TD rating for ART3 may be an indication of increased OOTL. This observation tends to support the findings of increased complacency in this ART. These findings also indicate that although complacent behavior was greatest in ARTs 1 and 3, the reasons behind such complacent behavior are different. While the automation bias in ART1 may be due to high workload, the automation bias in ART3 may be due to more complex reasons than simply higher workload.

SA scores were hypothesized to improve with access to agent reasoning—with the exception of SA3 scores in ART3. In this study, SA1 scores evaluated how well the

participant maintained a general awareness of their environment, with the idea that increased access to agent reasoning would also give the participant context for events within their environment, thus making certain events and situations more salient. Those who were more successful at this integration would then show improved performance on the route-selection task as well as improved SA2 scores (Hancock and Diaz 2002). SA1 scores did not improve with access to agent reasoning. However, with increased ART, SA1 scores improved substantially. This could indicate that additional access to reasoning made the route-selection task easier, which allowed participants more time to monitor their environment. However, since there was also a reduction in performance on the route-selection task, as well as demonstrated automation bias in ART3, it is more likely the improvement in SA1 scores was a result of neglecting duties in other tasks (i.e., an intertask trade-off). There was no significant difference in SA2 (comprehension) scores between ARTs; however, SA3 scores did show a significant upward trend across ARTs. This suggests that, while access to agent reasoning does not improve comprehension, it could incrementally improve an operator's ability to predict future outcomes. In previous studies, increased autonomous assistance did result in improved SA (Wright et al. 2013). However, the present findings indicate access to agent reasoning does little to improve SA. There were differences in SA scores dependent upon the ID factor for SV. High-SV individuals had higher SA1 and SA3 scores than their low-SV counterparts. This was most likely due to their increased ability to scan their environment (Lathan and Tracey 2002; Chen et al. 2008; Chen et al. 2010).

Access to agent reasoning appeared to have little influence on performance in the target-detection task. There were no significant differences in the mean number of targets correctly detected across ART. However, access to agent reasoning did mitigate the number of participant FAs reported. Signal Detection Theory (SDT) measured whether access to agent reasoning had any effect on sensitivity or selection criteria. Sensitivity to targets, assessed as *d'*, appeared to be slightly lower in the no-reasoning condition. Selection criteria were also lower in the no-reasoning condition. Thus, participants appeared to use a higher selection criterion when targets were more readily identifiable, and subsequently loosened their selection bias when target sensitivity was lower. This pattern of behavior could explain the greater number of false alarms reported in the no-reasoning condition. The presence of agent reasoning appears to have positively affected performance on the secondary target-detection task. While the overall number of targets detected did not differ among conditions, the sensitivity to target and selection criterion appeared to have been higher in the agent reasoning conditions, resulting in fewer reported FAs.

Operator trust in the agent was assessed objectively by evaluating incorrect rejections of the agent's suggestions (a potential indicator of distrust), and subjectively using the Usability and Trust Survey. The objective measure of operator trust indicated no difference in trust due to ART. However, subjective measures indicated access to agent reasoning reduced trust and usability evaluations. Increased transparency of agent reasoning resulted in increased trust and usability ratings; however, there was no associated improvement in performance. Interestingly, operators reported highest trust and usability in the conditions that also had the highest complacency and lowest in the condition that had the highest performance. In the conditions when the agent reasoning was not transparent, and when the agent reasoning was highly transparent, the participant's trust and usability evaluations were highest (albeit for potentially different reasons) even though they knew the agent was not completely reliable. However, in the condition with a moderate amount of ART, the participants reported lower trust and usability, indicating they were more critical of the agent recommendations in this condition, resulting in reduced complacency and improved performance.

3.6 Conclusion

The findings of the present study are important for the design of intelligent recommender and decision-aid systems. Keeping the operator engaged and in the loop is important for reducing complacency, which could allow lapses in system reliability to go unnoticed. To that end, we examined how agent transparency affected complacent behavior as well as task performance and trust. Access to agent reasoning was found to be an effective deterrent to complacent behavior when the operator has limited information about their task environment. Contrary to the position adopted by Paradis et al. (2005), operators do accept agent recommendations even when they do not know the rationale behind the suggestions. While the absence of agent reasoning appears to encourage automation bias, access to the agent's reasoning appears to allow the operator to calibrate their trust in the system, reducing automation bias and improving performance. This outcome is similar to findings previously reported by Helldin et al. (2014) and Mercado et al. (2015). However, the additional reasoning information created ambiguity for the operator, which encouraged complacency, resulting in reduced performance and poorer trust calibration. Prior work has shown that irrelevant or ambiguous information can increase workload and encourage complacent behavior (Chen and Barnes 2014; Westerbeek and Maes 2013), and these findings align with those. As such, caution should be exercised when considering how transparent to make agent reasoning and what information should be included.

This work represents the first of 2 studies exploring the effect of agent transparency on complacent behavior. In the follow-up study, the amount of information the operator has regarding the task environment will be increased. As a result of this increase, the amount of agent reasoning provided will also be increased to incorporate additional information into agent recommendations. This will allow us to compare differences in operator complacency and performance due to further operator knowledge of their task environment as well as that which results from greater access to agent reasoning.

4. Experiment 2

4.1 Overview

Experiment 2 investigated how access to the agent's reasoning affected the human operator's decision-making, task performance, SA, and complacent behavior in a multitasking environment when additional, sometimes competing, environmental information is available. It differed from Experiment 1 in 2 ways: first, the level of environmental information was increased, and second, the degree of ART, when available, was increased. Environmental information was displayed by icons appearing on the map, with events affecting both the original route and the proposed alternative displayed (see Fig. 25). ART was manipulated via RoboLeader's detailed notifications, which were expanded from Experiment 1 (EXP1) to include each of the icons affecting the area, along with weighing information as to how each event was factored into RL's recommendation.

Fig. 25 Icons indicating a potential event on the convoy's main route (solid line) and potential events on the proposed alternative route (dashed lines)

4.2 Stated Hypothesis

4.2.1 Complacent Behavior, Primary Task Performance, Trust in the Agent

We hypothesized that 1) access to agent reasoning would reduce complacent behavior, improve task performance, and increase trust in the agent, but 2) increased access to agent reasoning would increase complacent behavior, negatively impact performance, and reduce trust in the agent. Although decision time decreased with the access to agent reasoning in EXP1, the increase in agent transparency in this study was expected to increase DT (aside from clearly complacent behavior): ART1 < ART2 < ART3. Unlike EXP1, RL's messages were considerably longer in ARTs 2 and 3 than in ART1; as such, additional time was expected to be required for reading the messages. Participants were expected to take longer to process the information and reach their decision, resulting in a longer DT. Shorter response times may indicate less deliberation on the part of the operator before accepting or rejecting the agent recommendation. This could mean either positive complacent behavior or reduced task difficulty.

Hypothesis 1: Access to agent reasoning will reduce incorrect acceptances, ART1 > ART2, and increased transparency of agent reasoning will increase incorrect acceptances, ART2 < ART3. When agent reasoning is not available, incorrect acceptances will be greater than when agent reasoning is present, ART1 > ART2+3.

Hypothesis 2: Access to agent reasoning will improve performance (number of correct rejects and accepts) on the route-selection task, ART1 < ART2, and increased transparency of agent reasoning will reduce performance on the route-selection task, ART2 > ART3. When agent reasoning is not available, performance will be lower than when agent reasoning is present, ART1 < ART2+3.

Hypothesis 3: Access to agent reasoning will increase operator trust in the agent, ART1 < ART2, and increased transparency of agent reasoning will decrease operator trust in the agent, ART2 > ART3.

4.2.2 Workload

We hypothesize that increasing ART will, in turn, increase the operators' workload. In EXP1, increased access to agent reasoning reduced operator perceived workload. However, in this study, as the agent reasoning becomes more transparent the amount of information the operator must process has increased considerably from that presented in EXP1. It is expected that this increased mental demand will be reflected in the workload measures.

Hypothesis 4: Access to agent reasoning will increase operator workload, ART1 < ART2, and increased transparency of agent reasoning will increase operator

workload, ART2 < ART3. When agent reasoning is not available, workload will be lower than when agent reasoning is present, ART1 < ART2+3.

4.2.3 SA

We hypothesize that ART will support the operators' SA. Access to the agent reasoning will help the operator better comprehend how objects/events in the task environment affect their mission, thus informing their task of monitoring the environment surrounding the convoy and making them cognizant of potential risks. This understanding will also enable them to make more accurate projections regarding the future safety of their convoy. However, the addition of information that appears ambiguous to the operator will have a detrimental effect on both their ability continuously monitor their environment as well as their ability to correctly project future status.

Hypothesis 5: Access to agent reasoning will improve SA scores, and increased transparency of agent reasoning will improve SA2 scores but will reduce SA1 and SA3 scores:

- SA1: ART1 < ART2, ART2 > ART3;
- SA2: ART1 < ART2, ART2 < ART3;
- SA3: ART1 < ART2, ART2 > ART3.

4.2.4 Target-Detection Task Performance

We hypothesize that increasing ART will reduce performance in the target-detection task. The increased mental demand on the operator will affect their ability to effectively monitor the environment for threats. The increased amount of environmental information will also affect the operators' selection bias, resulting in increased false alarms.

Hypothesis 6: Access to agent reasoning will reduce performance in the target-detection task (fewer targets detected, higher FAs), ART1 > ART2, and increased transparency of agent reasoning will further reduce performance on the target-detection task, ART2 > ART3.

4.2.5 Individual Differences

The effects of ID in complacency potential, perceived attentional control, spatial ability, and working memory capacity on the operator's task performance, trust, and SA were also investigated. While the results of EXP1 did not always show differences due to ID factors, it is expected those results occurred because the operators did not experience as heavy of a cognitive load as expected. If that is the

case, the increased amount of environmental information and agent reasoning present in Experiment 2 (EXP2) should increase the cognitive burden and differences due to ID factors will become apparent.

Hypothesis 7: High-CPRS individuals will have fewer correct rejects on the route-planning task than low-CPRS individuals.

Hypothesis 8: High-CPRS individuals will have higher scores on the Usability and Trust Survey than low-CPRS individuals.

Hypothesis 9: High-CPRS individuals will have lower SA scores than low-CPRS individuals.

Hypothesis 10: IDs, such as SpA and PAC, will have differential effects on the operator's performance on the route-selection task and their ability to maintain SA.

Hypothesis 11: High-WMC individuals will have more correct rejects and higher SA2 and SA3 scores than low-WMC individuals.

4.3 Method

4.3.1 Participants

Seventy-three participants (ages 18–44) were recruited from the Sona Systems at UCF's Institute for Simulation and Training and Psychology Departments. Participants received their choice of compensation: either cash payment ($15/hr) or Sona Credit at the rate of 1 credit/hr. Thirteen potential participants were excused or dismissed from the study: 8 were dismissed early due to equipment malfunctions, one withdrew during training claiming they did not have time to participate, 2 fell asleep during their session and were dismissed, one could not pass the training assessments and was dismissed, and one did not pass the color-vision screening test and was dismissed. Those who were determined to be ineligible or withdrew from the experiment were paid for the amount of time they participated, with a minimum of 1 hr. Sixty participants (21 males, 39 females; Min_{age} = 18 years, Max_{age} = 44 years, M_{age} = 21.0 years) successfully completed the experiment and their data were used in the analysis.

4.3.2 Apparatus

The simulator and eye tracker were the same as in EXP1.

4.3.3 Surveys and Tests

All surveys, questionnaires, and tests were the same as in EXP1. Descriptive statistics pertaining to EXP2 ID measures are listed here. Since the ID measures

were dichotomized into high/low groups similar to those in EXP1, these groups were also compared between experiments to ensure consistent delineation between high- and low-group scores. For each ID measure, the high and low groups were found to be distinct from one another, and this difference was consistent between EXPs 1 and 2.

4.3.3.1 Attentional Control Survey

High/low group membership was determined by median split of all participants' scores (Min_{PAC} = 33, Max_{PAC} = 75, Mdn_{PAC} = 58, M_{PAC} = 57.6, SD_{PAC} = 8.16; PAC_{LOW} n = 29, PAC_{HIGH} n = 31).

4.3.3.2 Spatial Ability Tests

4.3.3.2.1 Cube Comparison Test

High/Low group membership was determined by median split of all participants' scores (Min_{SV} = 0.19, Max_{SV} = 0.88, Mdn_{SV} = 0.50, M_{SV} = 0.52, SD_{SV} = 0.14, SV_{LOW} n = 27, SV_{HIGH} n = 33).

4.3.3.2.2 Spatial Orientation Test

High/low group membership was determined by median split of all participants' scores (Min_{SOT} = 3.96, Max_{SOT} = 50.60, Mdn_{SOT} = 11.19, M_{SOT} = 13.79, SD_{SOT} = 8.48, SOT_{LOW} n = 27, SOT_{HIGH} n = 34).

4.3.3.3 CPRS

High/low group membership was determined by median split of all participants' scores (Min_{CPRS} = 25, Max_{CPRS} = 47, Mdn_{CPRS} = 37, M_{CPRS} = 36.8, $CPRS_{LOW}$ n = 28, $CPRS_{HIGH}$ n = 32).

4.3.3.4 RSPAN

WMC was evaluated by using the participants' total letter-set score (sum of all perfectly recalled letter sets), with higher numbers indicating greater WMC (Min_{RSPAN} = 10.0, Max_{RSPAN} = 54.0, Mdn_{RSPAN} = 31.0, MR_{SPAN} = 31.5, SD_{RSPAN} = 12.1). High/low group membership was determined by median split of all participants' scores, $RSPAN_{LOW}$ n = 29, $RSPAN_{HIGH}$ n = 31.

4.3.4 Experimental Design and Performance Measures

The study was a between-subjects experiment. Independent variables were ART level and ID factors. Dependent measures were route-selection task score, DT, target-detection task scores, workload, SA, and trust scores.

4.3.4.1 Independent Variables

ART was manipulated via RL messages (see Appendix K). In ART1, the agent recommended a course of action but otherwise offered no insight as to the reasoning behind the recommendation. In ART2, the agent recommended a course of action and gave the reason behind this recommendation. In ART3, the agent recommendation was the same as in ART2; however, the message also included information as to how long ago the information was received (e.g., 1 hr, 4 hr, 6 hr). RL messages in ARTs 2 and 3 included details about events denoted by the map icons for both primary and alternate routes, as well as weighing factors illustrating how RL used this information in its recommendation. Transcripts of RL messages for each ART are in Appendix J. Participants completed 3 missions in their assigned ART.

4.3.4.2 Dependent Measures

The dependent measures were the same as in EXP1.

4.3.5 Procedure

The procedure was the same as in EXP1.

4.4 Results

Results were analyzed using the same methods and procedures as outlined in EXP1.

4.4.1 Complacent Behavior, Primary Task Performance, Trust in the Agent

4.4.1.1 Complacent behavior

Hypothesis 1: Access to agent reasoning will reduce incorrect acceptances, ART1 > ART2, and increased transparency of agent reasoning will increase incorrect acceptances, ART2 < ART3. When agent reasoning is not available, incorrect acceptances will be greater than when agent reasoning is present, ART1 > ART2+3.

Descriptive statistics for incorrect acceptances and DTs at the locations where the agent recommendation should have been rejected are shown in Table 14.

Table 14 Descriptive statistics for incorrect acceptances and DTs sorted by ART level

		N	Mean	SD	SE	95% CI for mean
Incomplete acceptances	ART1	20	1.00	1.17	0.26	(0.45, 1.55)
	ART2	20	0.90	0.91	0.20	(0.47, 1.33)
	ART3	20	1.50	1.64	0.37	(0.73, 2.27)
Overall DT at reject locations (s)	ART1	20	11.14	3.68	0.82	(9.42, 12.87)
	ART2	20	11.51	3.35	0.75	(9.94, 13.08)
	ART3	20	12.30	3.96	0.89	(10.45, 14.16)
DT correct rejects (s)	ART1	20	10.84	3.45	0.77	(9.23, 12.45)
	ART2	20	11.25	3.19	0.71	(9.75, 12.74)
	ART3	20	12.52	4.21	0.94	(10.55, 14.49)
DT incorrect accepts (s)	ART1	11	12.17	5.76	1.74	(8.30, 16.05)
	ART2	12	14.37	4.49	1.30	(11.51, 17.22)
	ART3	12	12.39	4.60	1.33	(9.46, 15.31)

WMC score was found to be a significant predictor of incorrect acceptances, in that participants with lower WMC had more incorrect acceptances than those with greater WMC, $R^2 = .079$, $b = –0.03$, $t(58) = –2.23$, $p = .029$.

A between-groups ANOVA was conducted to assess the effect of ART on incorrect acceptances, and no significant effect was found (Fig. 26). Planned comparisons revealed the number of incorrect acceptances were lower in ART2 than in ART1; however, these differences were not significant.

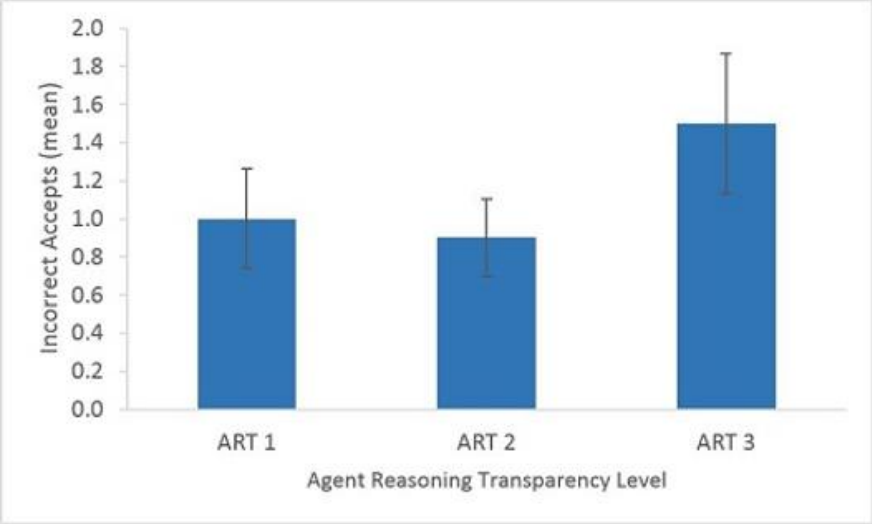

Fig. 26 Average number of incorrect acceptances by ART level; bars denote SE

Participants' scores were further analyzed by the number of incorrect acceptances per ART level (see Fig. 27). Chi-square analysis found no significant effect of ART

on the number of incorrect acceptances. Across all ART levels, 25 participants had no incorrect acceptances, and these were (roughly) equally distributed among ARTs, indicating the addition of agent reasoning had no more effect on performance than operator knowledge alone. The range of potential scores for incorrect acceptances was 0–6, and the range of participants' scores was 0–5. Thirty-five participants had at least 1 incorrect acceptance, and these scores were sorted into groups: <50% (score 3 or less) or >50% (score 4 or higher). The participants who made incorrect acceptances appeared to be evenly distributed among ARTs. Of these, 31 out of 35 participants scored under 50%. This is evidence that ART had little to no effect on the number of incorrect acceptances. It is interesting to note that no participants in ART2 had more than 3 incorrect acceptances. However, of the participants who had >50% incorrect acceptances, most were in ART3, which could be an indication that too much access to agent reasoning can have a detrimental effect on performance.

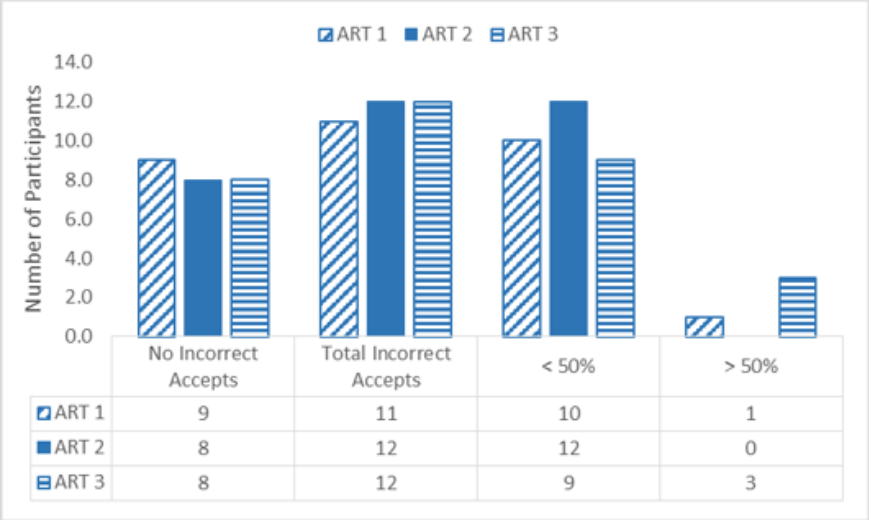

Fig. 27 Distribution of number of incorrect acceptances across ART level

As in EXP1, the DT for responses at the locations where the agent recommendation was incorrect was evaluated as a potential indicator of complacent behavior. It was hypothesized that DT would increase as ART increased, as participants should require additional time to process the extra information, particularly in EXP2 as the text conveying agent reasoning in ARTs 2 and 3 was much longer than the notification presented in ART1 (see Appendix J). Thus, reduced time could indicate less time spent on deliberation, which may imply complacent behavior. In addition to the overall time to respond, DTs for correct rejects and incorrect accepts were also examined (see Fig. 28). There was no significant effect of ART on overall DT. Overall DT was slightly shorter in ART1 than in ART2, and slightly shorter in ART2 than in ART3; however, these differences were not significant. There was

no significant effect of ART on DT for correct rejections. Mean decision times for correct rejections were slightly shorter in ART1 than in ART2, and shorter in ART2 than in ART3, but also were not significant. There was no significant main effect of ART on DT for incorrect acceptances. Mean DTs for incorrect acceptances were longer in ART2 than in ART1 and ART3. DTs remained relatively unchanged across ART levels; however, in ART2 DTs for incorrect acceptances were longer than DTs for correct rejects. This is evidence these incorrect responses were most likely due to errors in judgment rather than complacent behavior. Paired t-tests were used to compare differences between DTs for correct and incorrect responses within each ART. The largest difference in DT was in ART2, $t(11) = -1.57$, $p = .146$, $d = 0.47$, which had a medium-effect size although the p-value was not significant. Although these results did not achieve statistical significance, it is interesting that DTs between correct and incorrect responses are similar in ARTs 1 and 3, while those in ART2 indicate that participants in this condition spent more time in deliberation when their response was incorrect than when it was correct, and the medium-effect size indicates this difference is meaningful.

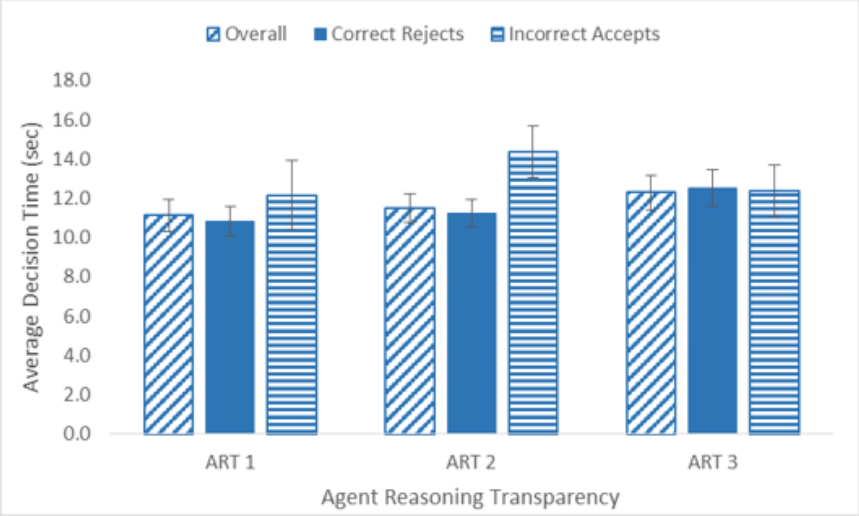

Fig. 28 Average DT in seconds for participant responses at decision points where the agent recommendation was incorrect: DTs are shown for all responses (overall), correct rejections, and incorrect acceptances sorted by ART level; Bars denote SE.

4.4.1.2 Route-Selection Task Performance

Hypothesis 2: Access to agent reasoning will improve performance (number of correct rejects and accepts) on the route-selection task, ART1 < ART2, and increased transparency of agent reasoning will reduce performance on the route-selection task, ART2 > ART3. When agent reasoning is not available, performance will be lower than when agent reasoning is present, ART1 < ART2+3.

Descriptive statistics for route-selection task scores and DTs for all decision points across 3 missions are shown in Table 15.

Table 15 Descriptive statistics for route-selection scores and DTs sorted by ART level

		N	Mean	SD	SE	95% CI for mean
Route-selection score	ART1	20	13.20	3.46	0.77	(11.58, 14.82)
	ART2	20	13.30	3.18	0.71	(11.81, 14.79)
	ART3	20	13.40	3.28	0.73	(11.86, 14.94)
Overall DT(s)	ART1	20	10.86	3.04	0.68	(9.44, 12.28)
	ART2	20	12.53	3.09	0.69	(11.08, 13.97)
	ART3	20	12.52	4.91	1.10	(10.22, 14.81)
DT correct responses (s)	ART1	20	10.32	2.79	0.62	(9.02, 11.63)
	ART2	20	11.95	3.40	0.76	(10.36, 13.54)
	ART3	20	11.79	3.98	0.89	(9.33, 13.65)
DT incorrect responses (s)	ART1	20	13.06	5.39	1.21	(10.54, 15.59)
	ART2	19	15.21	3.05	0.70	(13.74, 16.68)
	ART3	17	12.65	4.39	1.07	(10.40, 14.91)

Participants who scored higher on the CPRS, indicating a greater potential to demonstrate complacent behavior when interacting with automation, performed worse on the route-selection task than their counterparts, $R^2 = .138$, $b = –.276$, $t(58) = –3.04$, $p = .004$. Participants who scored lower on the SOT, demonstrating greater spatial-orientation abilities, also performed better on the route-selection task than their counterparts, $R^2 = .064$, $b = –.111$, $t(58) = –2.00$, $p = .051$.

A between-groups ANOVA was conducted to assess the effect of ART on route-selection scores and found no significant effect. Planned comparisons revealed route-selection scores were higher in ART2 than in ART1 and higher in ART3 than in ART2. The results trended as predicted; however, they were not significant.

Examining the distribution of scores, the potential range of scores for the route-selection task was 0–18 and the range of participants' scores was 7–18 (see Fig. 29). Of these, 4 participants scored 18/18, 3 of whom were in ART3. Only 9 participants scored 50% or less; the majority scored 67% or higher. For comparative purposes, scores were sorted into similar groups as in EXP1 (i.e., 17–15, 14–12, <12). Interestingly, scores in each ART appear to be nearly evenly distributed among the groups. This does support the hypothesis, as performance in the agent reasoning conditions appears to be no better than in the notification-only condition.

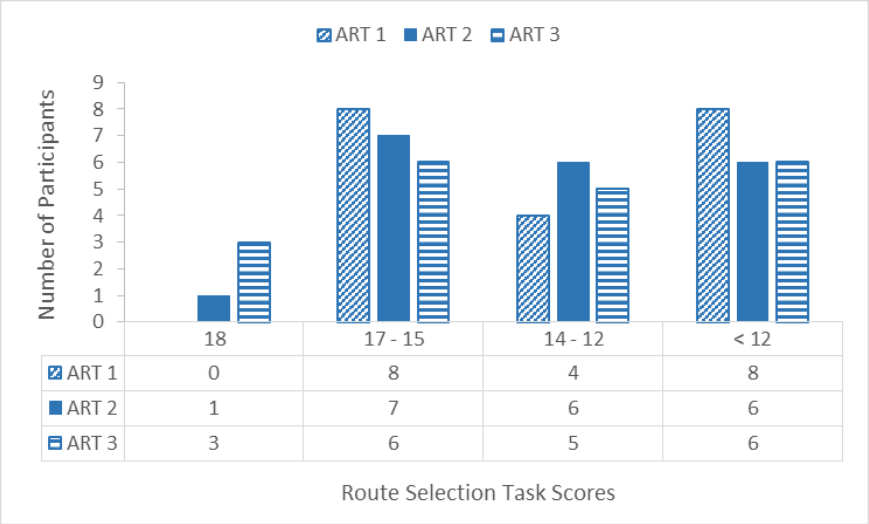

Fig. 29 Distribution of scores for the route-selection task across ART levels

Planned comparisons revealed DTs were longer in ART2 than in ART1, $t(38.0) = 1.72$, $p = .094$, $r_c = .27$, but not significantly different than in ART3. Overall, DTs were longer in the conditions with agent reasoning than without (ART1 < ART2+3), $t(46.5) = 1.77$, $p = .083$, $r_c = .25$. These results were not significant, but they do follow the same pattern as those for the task-performance evaluation.

Overall, decision times for acceptances were compared to those for rejections of the agent recommendation using paired t-tests; this difference was marginally significant, $t(59) = –1.91$, $p = .061$, $d = 0.17$, across ART levels. Overall, DTs for correct responses were significantly shorter than those for incorrect responses, $t(55) = –5.20$, $p < .001$, $d = 0.58$. Within each ART, this difference was greater in ART2, $t(18) = –3.61$, $p = .002$, $d = 0.95$, than in ART1, $t(19) = –3.21$, $p = .005$, $d = 0.67$, and smallest in ART3, $t(16) = –2.56$, $p = .021$, $d = 0.23$ (see Fig. 30). DTs for incorrect responses among ARTs were evaluated, and there was no significant difference between ART1 and ART2 and a marginally significant difference between ART2 and ART3, $t(28.11) = –2.00$, $p = .055$, $d = 0.76$. While not offering additional support for the hypothesis, the difference in mean DT for incorrect responses demonstrated in ART3 could be indicative of some participants' increased complacent behavior in the highest agent reasoning condition.

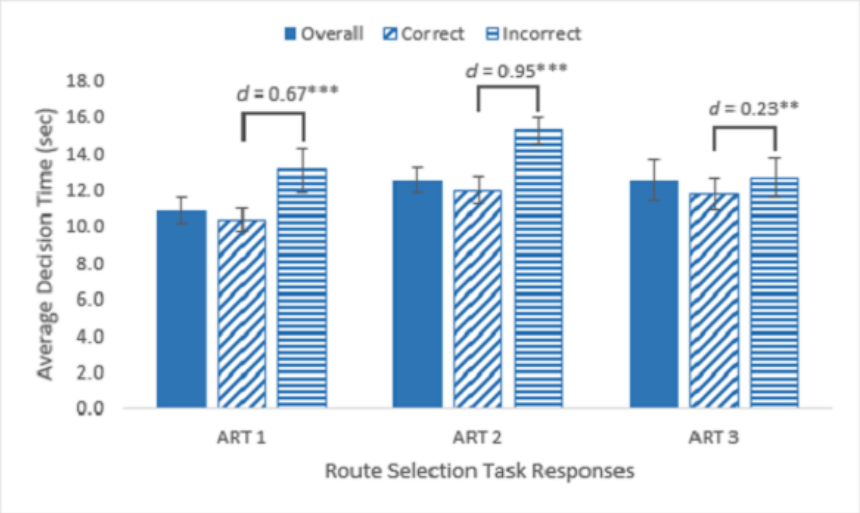

Fig. 30 Comparison of average DTs for correct responses and incorrect responses shown by ART level; bars denote SE

4.4.1.3 Operator Trust Evaluation

Hypothesis 3: Access to agent reasoning will increase operator trust in the agent, ART1 < ART2, and increased transparency of agent reasoning will decrease operator trust in the agent, ART2 > ART3.

Descriptive statistics for incorrect rejections and the Usability and Trust Survey scores are shown in Table 17.

Table 16 Descriptive statistics for incorrect rejections and Usability and Trust Survey results across ART level

		N	Mean	SD	SE	95% CI for mean
Incorrect rejections	ART1	20	3.75	3.49	0.78	(2.12, 5.38)
	ART2	20	3.80	2.76	0.62	(2.51, 5.09)
	ART3	20	3.10	3.04	0.68	(1.68, 4.52)
Usability and Trust Survey	ART1	20	91.30	19.29	4.31	(82.27, 100.33)
	ART2	20	91.20	15.73	3.52	(83.84, 98.56)
	ART3	20	93.60	13.03	2.91	(87.50, 99.70)
Usability responses	ART1	20	40.35	7.18	1.61	(36.99, 43.71)
	ART2	20	39.45	6.05	1.35	(36.62, 42.28)
	ART3	20	41.60	5.70	1.27	(38.93, 44.27)
Trust responses	ART1	20	50.95	13.08	2.92	(44.83, 57.07)
	ART2	20	51.75	11.19	2.50	(46.51, 56.99)
	ART3	20	52.00	8.61	1.93	(47.97, 56.03)

CPRS was found to be a significant predictor of incorrect rejections, $R^2 = .110$, $b = 0.23$, $t(58) = 2.67$, $p = .010$. Persons who scored low in CP had fewer incorrect

rejections than their higher-CP counterparts, which could be an indication of better calibrated trust of the agent for those individuals.

Examining the distribution of incorrect rejections at those locations where the agent recommendation was correct across ARTs showed, 11 participants had no incorrect rejections, and this number appears to be relatively even across ARTs (see Fig. 31). The range for potential scores for incorrect rejections was 0–12, and the range of participants' scores was 0–9. Forty-nine participants had at least one incorrect rejection, and these scores were sorted into <50% (score 5 or less) and >50% (score 6 or higher). While scores in ART1 appeared to near the rate for chance, the majority of scores in ARTs 2 and 3 were below 50%, indicating that access to agent reasoning was helpful in reducing incorrect rejections.

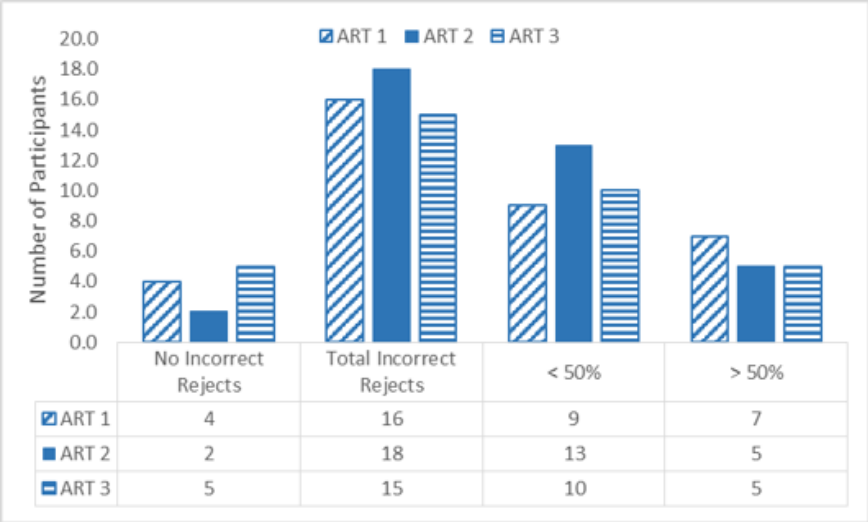

Fig. 31 Distribution of scores for incorrect rejections sorted by ART level

Planned comparisons revealed there were more incorrect rejections in ART2 than in ART1 and ART3; however, these differences were not significant.

As in EXP1, the DT for responses at the locations where the agent recommendation was correct was evaluated as a potential indicator of operator trust. It was hypothesized that DT would increase as ART increased, as participants should require additional time to process the extra information. Thus, increased time could indicate more time spent on deliberation, which may imply lower trust. In addition, DTs for incorrect rejections of the agent recommendation at those locations could be indicative of complacent behavior (i.e., reduced DTs for incorrect responses). There was no significant effect of ART on overall DT at the agent's correct locations (see Fig. 32). Planned comparisons show that overall DTs in ART2 were longer than those in ART1, $t(57) = 2.00$, $p = .051$, $r_c = .26$, but not significantly longer than those in ART3. Overall, DTs were longer in the conditions with agent

reasoning access than in the notification-only condition—(ART1 – ART2+3), $t(57) = 1.86$, $p = .068$, $r_c = .24$—and this difference was marginally significant. DTs for correct accepts were significantly higher in the agent reasoning conditions than in the notification-only condition: (ART1 – ART2+3), $t(48.2) = 2.44$, $p = .018$, $r_c = .33$. DTs for correct responses were shorter in ART1 than in ART2, $t(37.4) = 2.48$, $p = .018$, $r_c = .38$, but not significantly different in ART2 than in ART3. DTs for incorrect responses were not significantly longer in ART2 than in ART1, and significantly longer than in ART3, $t(31.0) = –2.21$, $p = .042$, $r_c = .36$.

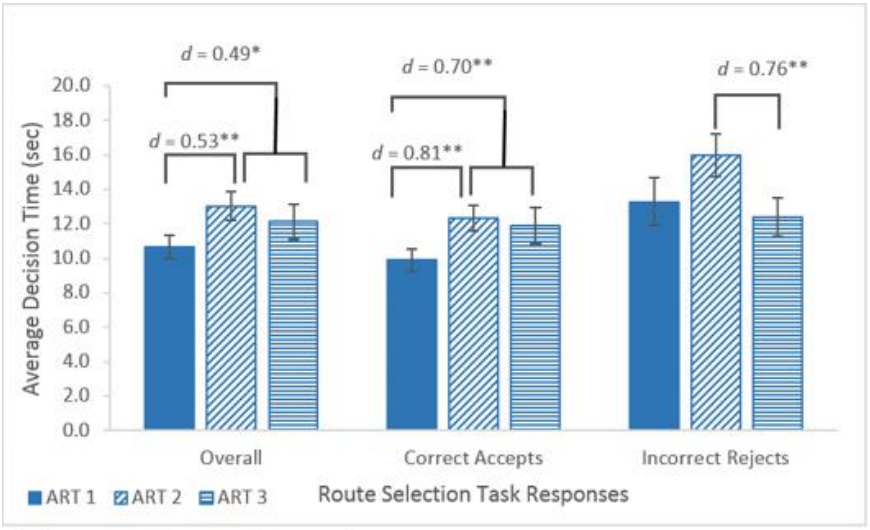

Fig. 32 Average DTs in seconds at the locations where the agent recommendation was correct, sorted by correct/incorrect selections for each ART level; bars denote SE

Paired t-tests were used to compare differences between DTs for correct acceptances and incorrect rejections within each ART at those locations where the agent recommendation was correct (see Fig. 33). DTs for incorrect rejections were significantly longer than for correct acceptances in ART1, $t(11) = –3.36$, $p = .004$, $d = 0.79$, and ART2, $t(17) = –3.40$, $p = .003$, $d = 0.84$. However, there was no difference between the 2 in ART3. While the difference in DTs in ARTs 1 and 2 could indicate difficulty integrating the information, resulting in incorrect choices, the lack of the same difference in ART3 could indicate complacent behavior.

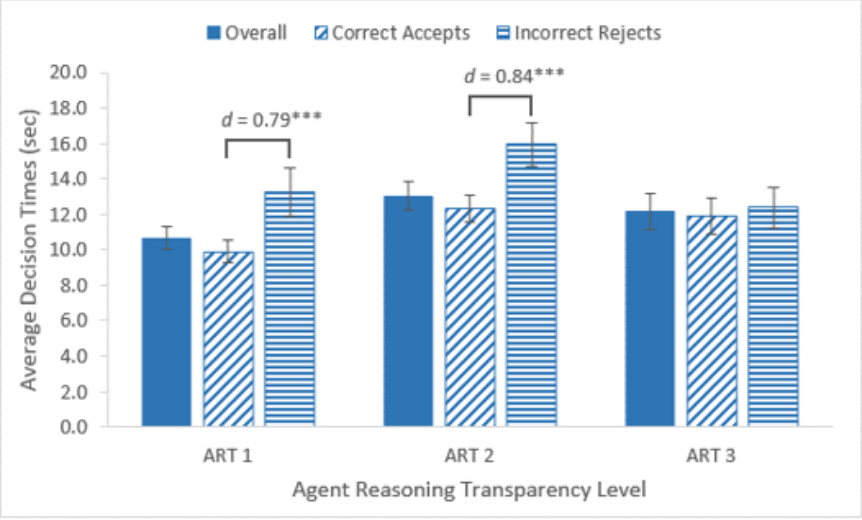

Fig. 33 Average DT in seconds for correct acceptances and incorrect rejections within each ART level; bars denote SE

Operator trust was also evaluated using the Usability and Trust Survey. CPRS was found to be a significant predictor of scores on the Usability and Trust Survey, R^2 = .120, b = –1.26, $t(58)$ = –2.81, p = .007. Participants who scored higher on the CPRS measure rated the agent as being less usable and trusted than did their counterparts.

A 1-way ANOVA evaluating overall usability and trust scores found no significant effect of ART. Planned comparisons revealed scores were higher in ART1 than in ART2 and higher in ART3 than in ART2; however, these differences were not significant.

The Usability and Trust Survey is a combination of surveys measuring usability and trust. These individual surveys were also evaluated separately to assess whether the findings were due to mainly operator trust or perceived usability.

Planned comparisons revealed trust scores were higher in ART2 than in ART1 and higher in ART3 than in ART2; however, these differences were not significant.

Planned comparisons revealed scores were slightly higher in ART1 than in ART2 and higher in ART3 than in ART2; however, these differences were not significant.

4.4.2 Workload Evaluation

Hypothesis 4: Access to agent reasoning will increase operator workload, ART1 < ART2; increased transparency of agent reasoning will increase operator workload, ART2 < ART3. When agent reasoning is not available, workload will be lower than when agent reasoning is present, ART1 < ART2+3.

ART had no significant effect on participants' global workload (see Fig. 34). Planned contrasts revealed no overall difference in participant workload when agent reasoning was available compared to the no-reasoning condition, (ART1 – ART2+3). Participants in ART1 (M = 67.03, SD = 10.87) reported higher workload than those in ART2 (M = 62.80, SD = 13.78), and workload was higher in ART2 than in ART3 (M = 61.48, SD = 11.58). The nonsignificant omnibus p-value, along with the small effect sizes, indicate that although workload scores decreased as ART increased there was no significant difference among ARTs.

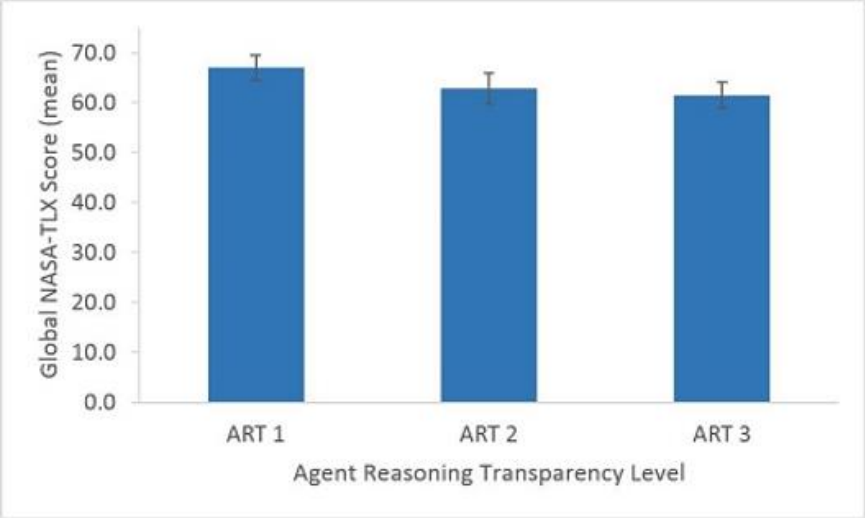

Fig. 34 Average global NASA-TLX scores by ART level; bars denote SE

Cognitive workload was also evaluated using several ocular indices. Descriptive statistics are shown in Table 17. Not all participants had complete eye-measurement data, so this N was reduced (ART1 N = 18, ART2 N = 17, ART3 N = 17) and unweighted results reported. Eye-tracking data were evaluated using the same planned comparisons as the subjective workload measure.

Table 17 Descriptive statistics for eye-tracking measures by ART condition

		N	Mean	SD	SE	95% CI for mean
PDia (mm)	ART1	18	3.77	0.58	0.14	(3.48, 4.06)
	ART2	17	3.43	0.32	0.08	(3.26, 3.59)
	ART3	17	3.48	0.36	0.09	(3.29, 3.66)
FD (ms)	ART1	18	4864.48	620.01	146.14	(4556.16, 5172.80)
	ART2	17	4949.58	701.14	170.05	(4589.09, 5310.07)
	ART3	17	4995.22	680.51	165.05	(4645.33, 5345.10)
FC	ART1	18	279.20	38.57	9.09	(260.01, 298.38)
	ART2	17	263.89	43.44	10.54	(241.55, 286.22)
	ART3	17	271.67	32.62	7.91	(254.90, 288.44)

ART did not have a significant effect on participants' PDia (see Fig. 35); however, there was a marginally significant linear trend, $F(1,49) = 3.81$, $p = .057$, $\omega^2 = .05$, indicating workload decreased as ART increased. Planned contrasts revealed a significant difference in participant workload (as inferred via PDia) when agent reasoning was available, compared to the no-reasoning condition, (ART1 – ART2+3), $t(23.1) = -2.12$, $p = .045$, $r_c = .40$. Participants in ART1 had larger pupil diameters than those in ART2, $t(26.5) = -2.18$, $p = .039$, $r_c = .39$. However, there was no significant difference in workload (as inferred via PDia) between ARTs 2 and 3.

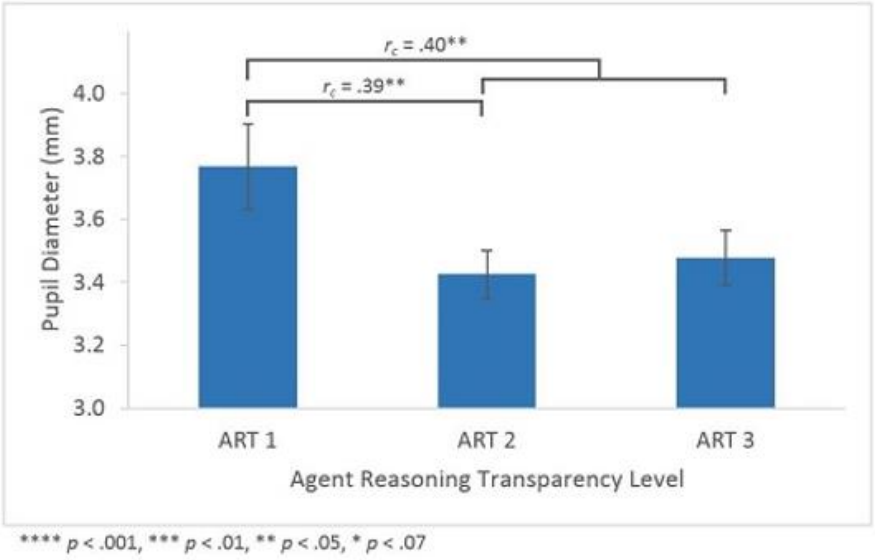

Fig. 35 Average participant PDia by ART level; bars denote SE

ART did not have a significant effect on participants' FC. Participants in ART1 had fewer fixations than those in ART2, who in turn had fewer fixations than those in

ART3. While these results trend in the hypothesized direction of increased workload as ART increases, the findings are not significant.

ART did not have a significant effect on participants' FD. Participants in ART2 had shorter fixations than those in ART1 and ART3. While these results indicate the addition of ART could alleviate workload, the results were not significant and the effect sizes were small.

In EXP1, the NASA-TLX factors were also examined individually; so, this analysis is repeated for EXP2 results. An omnibus Multivariate ANOVA indicated there was no significant difference across ARTs for any individual factor. Individual evaluations of each factor across ART were made by one-way ANOVA using Bonferroni correction, $\alpha = .008$ (see Table 18).

Table 18 Evaluation of NASA-TLX workload factors across ART conditions

	Mean (SD)			One-way ANOVA ($\alpha = .008$)		Planned comparisons (Cohen's *d*)		
	ART1	**ART2**	**ART3**	***F*(2,57)**	**ω^2**	**ART1–2**	**ART2–3**	**ART1–2+3**
MD	83.75 (12.45)	76.50 (20.27)	72.25 (20.10)	2.09	.04	0.34	0.20	0.50*
PhyD	21.00 (12.94)	15.25 (8.66)	13.50 (9.61)	2.76*	.06	0.46	0.14	0.61**
TD	54.25 (23.69)	51.25 (24.00)	46.00 (19.10)	0.70	.01	0.11	0.20	0.24
Perf	52.75 (20.99)	49.50 (19.93)	55.00 (18.06)	0.39	.02	0.14	0.23	0.02
Effort	73.75 (17.08)	73.75 (19.79)	68.50 (19.67)	0.52	.02	0.00	0.23	0.13
Frust	45.00 (25.75)	43.25 (26.77)	42.25 (21.67)	0.06	.03	0.06	0.03	0.09

** $p < .05$; * $p < .07$

Mental demand was the factor contributing the most to workload, and ART1 elicited greater MD than ARTs 2 or 3 (see Fig. 36). Although this difference did not reach significance, planned comparisons among ART levels indicate the medium–large-effect sizes for the differences between ART1 and the RL conditions ARTs 2 and 3 were significant. This is evidence that the presence of agent reasoning alleviates MD, contradicting the stated hypothesis that workload in ART1 would be lower than in ARTs 2 and 3. Physical demand contributed the least to overall workload. While the difference between ARTs 1 and 2 had a medium-effect size, it did not reach significance ($p = .091$). However, there was a significant difference

between the no-reasoning condition (ART1) and the transparent-reasoning conditions (ART 2+3).

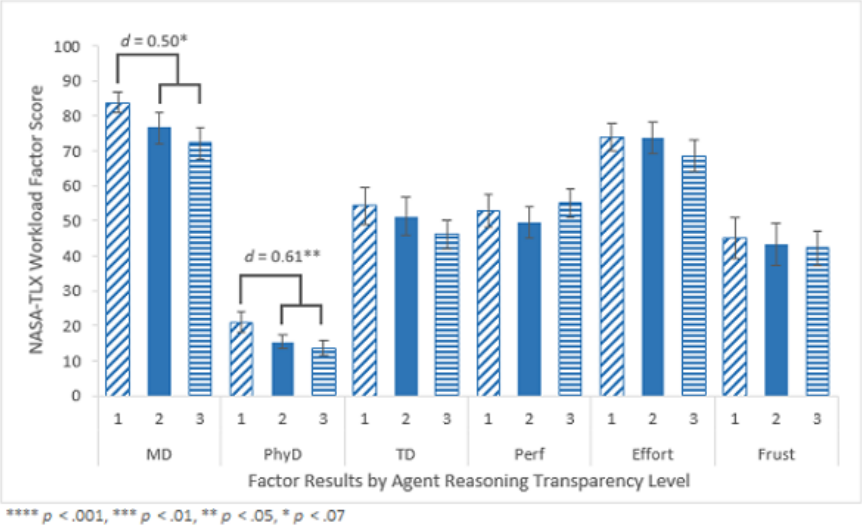

Fig. 36 Average NASA-TLX workload factor scores by ART level; bars denote SE

Unlike EXP1, there was no significant difference in factors Temporal Demand or Effort across ARTs. However, there was an interesting negative correlation between TD and the number of hours of sleep the participant reported for the previous night ($r = –.26$, $p = .042$), indicating those who had less sleep found the task more demanding overall.

4.4.3 SA Evaluation

Hypothesis 5: Access to agent reasoning will improve SA scores, and increased transparency of agent reasoning will improve SA2 scores but will reduce SA1 and SA3 scores:

- SA1: ART1 < ART2, ART2 > ART3;
- SA2: ART1 < ART2, ART2 < ART3;
- SA3: ART1 < ART2, ART2 > ART3.

Descriptive statistics for SA scores are shown in Table 19.

Table 19 Descriptive statistics for SA scores by ART level

		N	Mean	SD	SE	95% CI for mean	Min	Max
SA1	ART1	20	1.60	4.31	0.96	(–0.42, 3.62)	–6	10
	ART2	20	2.25	3.84	0.86	(0.45, 4.05)	–6	10
	ART3	20	1.55	5.43	1.21	(–0.99, 4.09)	–7	10
SA2	ART1	20	14.80	3.35	0.75	(13.23, 16.37)	9	20
	ART2	20	13.20	7.15	1.60	(9.85, 16.55)	0	24
	ART3	20	15.20	6.28	1.40	(12.26, 18.14)	1	25
SA3	ART1	20	2.90	9.40	2.10	(–1.50, 7.30)	–16	16
	ART2	20	0.45	8.51	1.90	(–3.53, 4.43)	–18	16
	ART3	20	2.00	8.78	1.96	(–2.11, 6.11)	–14	18

WMC scores were found to be a significant predictor of SA1 scores, $R^2 = .069$, $b = 0.10$, $t(58) = 2.07$, $p = .043$. Participants who scored higher on the WMC measure scored higher on SA1 queries than their counterparts.

Planned comparisons revealed SA1 scores were higher in ART2 than in ART1 or ART3; however, these differences were not significant.

SV scores ($r = .27$, $p = .018$) correlated significantly with SA2 scores, but were not found to be a significant predictor of SA2 scores. WMC scores—$R^2 = .143$, $b = 0.18$, $t(58) = 3.11$, $p = .003$—and SOT scores—$R^2 = .208$, $b = –0.36$, $t(58) = –3.90$, $p < .001$—were found to be significant predictors of SA2 scores. Participants who scored higher on the WMC and SV measures, or who performed better on the SOT, scored higher on SA2 queries than their counterparts.

A 1-way ANOVA evaluating SA2 scores found no significant effect of ART. Planned comparisons revealed no change in scores between ART1 and ART2, and scores in ART3 were slightly higher than in ART2; however, this difference was not significant.

CPRS scores ($r = –.25$, $p = .026$) and SOT scores ($r = –.27$, $p = .018$) correlated significantly with SA3 scores. Participants who scored lower on the CPRS, indicating a lower potential for complacent behavior, as well as those who performed better on the SOT, scored higher on SA3 queries than their counterparts.

Planned comparisons revealed SA3 scores in ART1 were higher than those in ART2 and scores in ART2 were lower than in ART3. These results were contrary to the stated hypothesis, in that SA3 scores were lowest in ART2; however, these results were not significant.

4.4.4 Task-Detection Task Performance

Hypothesis 6: Access to agent reasoning will reduce performance on the target-detection task (fewer targets detected, higher FAs), ART1 > ART2, and increased transparency of agent reasoning will further reduce performance on the target-detection task, ART2 > ART3.

Descriptive statistics for target-detection measures are shown in Table 20.

Table 20 Descriptive statistics for target-detection task measures by ART level

		N	Mean	SD	SE	95% CI for mean	Min	Max
Targets detected (count)	ART1	20	45.25	10.96	2.45	(40.12, 50.38)	24	59
	ART2	20	47.65	10.74	2.40	(42.62, 52.68)	30	73
	ART3	20	40.30	13.27	2.97	(34.09, 46.51)	18	61
FAs (count)	ART1	20	16.30	6.18	1.38	(13.41, 19.19)	4	28
	ART2	20	16.65	4.97	1.11	(14.33, 18.97)	11	26
	ART3	20	15.90	6.12	1.37	(13.04, 18.76)	6	26
d′	ART1	20	2.30	0.40	0.09	(2.11, 2.49)	1.62	2.95
	ART2	20	2.38	0.35	0.08	(2.21, 2.54)	1.81	3.32
	ART3	20	2.19	0.44	0.10	(1.99, 2.39)	1.49	2.88
β	ART1	20	2.64	0.34	0.08	(2.48, 2.80)	2.17	3.24
	ART2	20	2.59	0.28	0.06	(2.46, 2.72)	1.88	2.96
	ART3	20	2.65	0.39	0.09	(2.47, 2.83)	2.14	3.51

SV scores were found to be significant predictors of total number of targets detected, $R^2 = .143$, $b = 32.15$, $t(58) = 3.12$, $p = .003$. Participants who scored higher in SV, indicating a greater ability to mentally manipulate objects in 3-D space, also detected more targets in their environment than their counterparts.

Planned comparisons revealed the number of targets detected was not significantly different in ART2 than in ART1 and significantly higher in ART2 than in ART3, $t(57) = –1.98$, $p = .052$, $r_c = .25$ (see Fig. 37). While access to agent reasoning did not appear to improve performance on the target-detection task, increasing the amount of agent reasoning did result in a decline in performance, indicating the participants may have become overwhelmed.

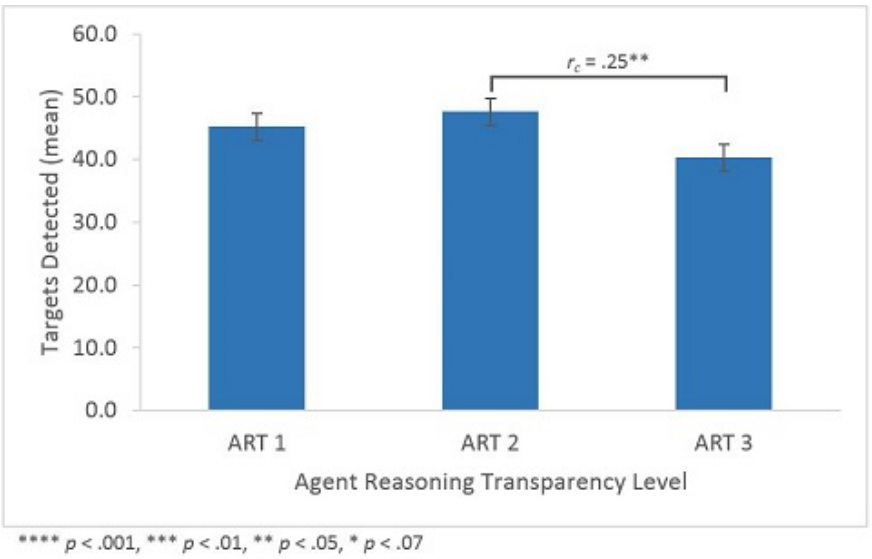

Fig. 37 Average number of targets detected by ART level; bars denote SE

Planned comparisons revealed the number of FAs was higher in ART2 than in ART1 and ART3; however, these differences were not significant.

Results of the target-detection task were also evaluated using SDT to determine if there were differences in sensitivity (*d'*) or selection bias (β or Beta) between the 3 ARTs. There was no significant effect of ART on *d*'. Participants were slightly more sensitive to targets in ART2 than in ART1 or ART3; however, these differences did not achieve statistical significance. Evaluating β across ART showed no significant effect of ART on β scores. Beta scores were slightly lower in ART2 than in ART1 and ART3; however, these differences were not significant. In an information-rich environment, ART appears to have no effect on sensitivity to targets or target-selection criterion.

4.4.5 ID Evaluations

4.4.5.1 Complacency Potential

CP was evaluated via the CPRS scores. The effect of CP on several measures of interest across ART level were evaluated via 2-way, between-groups ANOVAs, α = .05. Post hoc t-tests within each ART compared performance differences between high/low group memberships. Descriptive statistics for CP, as measured using the CPRS, are shown in Tables 21 and 22.

Table 21 Descriptive statistics for CPRS scores by ART level

							Mdn split count	
Group	**N**	**Min**	**Max**	**Mdn**	**Mean**	**SD**	**Hi**	**Lo**
Overall	60	25	47	37.00	36.83	4.38	32	28
ART1	20	25	41	35.00	35.00	4.21	8	12
ART2	20	32	47	40.00	39.05	3.53	15	5
ART3	20	31	47	35.50	36.45	4.54	9	11

Table 22 Descriptive statistics for high/low CPRS scores by ART level

		N	**Mean**	**SD**	**SE**	**95% CI for mean**
ART1	Low CPRS	12	32.42	3.34	0.96	(30.29, 34.54)
	High CPRS	8	38.88	1.36	0.48	(37.74, 40.01)
ART2	Low CPRS	5	34.80	1.79	0.80	(32.58, 37.02)
	High CPRS	15	40.47	2.72	0.70	(38.96, 41.97)
ART3	Low CPRS	11	33.18	1.54	0.46	(32.15, 34.21)
	High CPRS	9	40.44	3.64	1.21	(37.64, 43.25)

Hypothesis 7: High-CPRS individuals will have fewer correct rejects on the route-planning task than low-CPRS individuals.

A 2-way, between-groups ANOVA revealed no significant interaction between CPRS and ART on the number of correct rejects in the route-planning task; however, there was a significant main effect of CPRS on the number of correct rejects across ART, $F(1,54) = 7.51$, $p = .008$, $\eta_p^2 = .12$ (see Fig. 38). Post hoc comparisons between high/low CPRS groups within each ART level show that high-CPRS and low-CPRS individuals had similar route-selection scores in ART1; however, low-CPRS participants had more correct rejects in ART2, $t(18) = 2.17$, $p = .044$, $d = 1.37$, and ART3, $t(18) = 2.69$, $p = .015$, $d = 1.20$. When agent reasoning was not available there was no difference in correct rejects between high- and low-CPRS persons. However, when agent reasoning was available, participants with low CP had more correct rejects than those with high CP, and this difference became greater as ART increased.

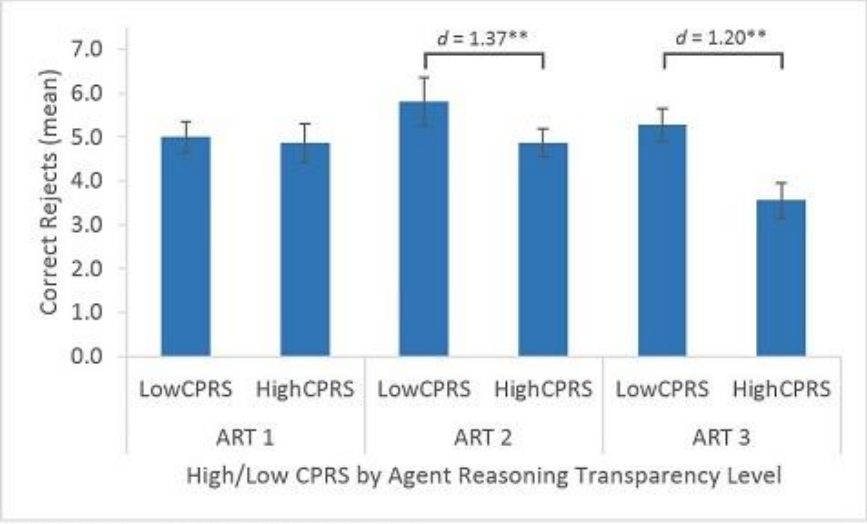

Fig. 38 Average number of correct rejects by high/low CPRS-score group sorted by ART level; bars denote SE

Hypothesis 8: High-CPRS-score individuals will have higher scores on the Usability and Trust Survey than low-CPRS-score individuals.

A 2-way, between-groups ANOVA revealed no significant interaction between CPRS score and ART on Usability and Trust Survey scores nor any significant main effect of CP on usability scores.

Hypothesis 9: High-CPRS-score individuals will have lower SA scores than low-CPRS-score individuals.

A 2-way, between-groups ANOVA revealed no significant interaction between CPRS scores and ART on SA1 scores; however, there was a significant main effect of CP on SA1 scores across ART, $F(1,54) = 4.12$, $p = .047$, $\eta_p^2 = .12$ (see Fig. 39). Post hoc comparisons between high/low CPRS-score groups within each ART level show that low-CP individuals had higher SA1 scores in each ART—ART1, $t(18) = 0.93$, $p = .365$, $d = 0.42$; ART2, $t(18) = 1.05$, $p = .310$, $d = 0.72$; and ART3, $t(18) = 1.54$, $p = .142$, $d = 0.69$—than their high-CP counterparts, and while these post hoc comparisons did not reach statistical significance, the medium–large-effect sizes indicate this difference is meaningful in each ART. Thus, in a high-information environment low-CP individuals monitored their environment better than high-CP individuals.

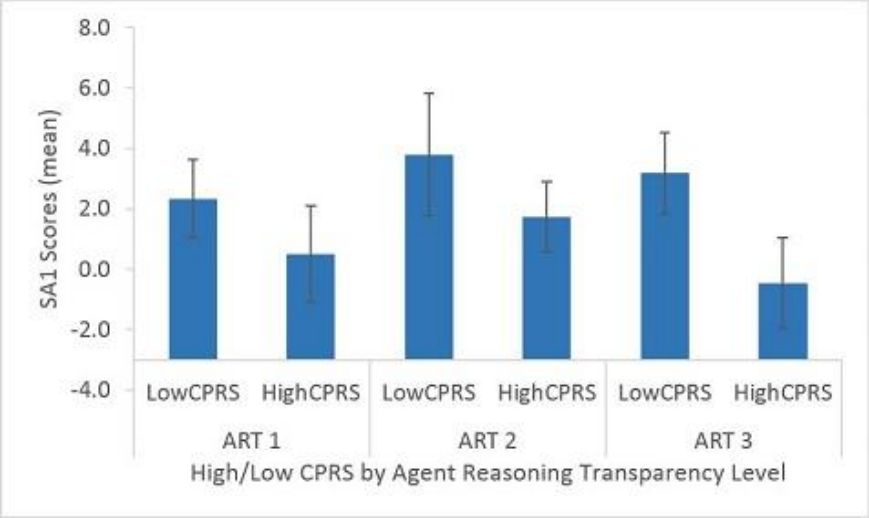

Fig. 39 Average Level 1 situation awareness (SA1) scores by high/low CPRS group sorted by ART level; bars denote SE

A 2-way, between-groups ANOVA revealed no significant interaction between CPRS and ART on SA2 scores nor any significant main effect of CPRS on SA2 scores across ART. A 2-way, between-groups ANOVA revealed no significant interaction between CPRS and ART on SA3 scores nor any significant main effect of CPRS on SA3 scores across ART.

4.4.5.2 Spatial Ability (SOT and SV) and PAC

Hypothesis 10: Individual differences, such as SpA and PAC, will have differential effects on the operator's performance on the route-selection task and their ability to maintain SA.

The effects of ID factors and ART level on route-selection performance were evaluated via 2-way, between-groups ANOVAs, $\alpha = .05$. When Levene's Test of Equality of Error Variance was significant, the evaluation was repeated at $\alpha = .01$. Post hoc t-tests within each ART compared performance differences between high/low group memberships for each ID factor. SOT is reverse-scored, so lower test scores imply greater spatial ability (high-SOT group), while SV and PAC are scored normally (higher test scores imply greater ability). Descriptive statistics for SOT, SV, and PAC are shown in Tables 23 and 24.

Table 23 Descriptive statistics for SOT, SV, and PAC by ART level

								Mdn split count	
	Group	**N**	**Min**	**Max**	**Mdn**	**Mean**	**SD**	**Hi**	**Lo**
SOT	Overall	60	3.96	33.01	11.19	13.39	7.40	30	30
	ART1	20	4.58	27.00	9.26	12.75	7.08	12	8
	ART2	20	4.52	33.01	13.74	14.71	8.14	8	12
	ART3	20	3.96	27.81	10.23	12.71	7.15	10	10
SV	Overall	60	0.19	0.88	0.50	0.52	0.14	30	30
	ART1	20	0.36	0.76	0.54	0.52	0.11	12	8
	ART2	20	0.36	0.88	0.51	0.53	0.13	13	7
	ART3	20	0.19	0.83	0.48	0.50	0.17	8	12
PAC	Overall	60	33	75	58.00	57.55	8.23	31	29
	ART1	20	33	74	57.50	56.35	8.87	10	10
	ART2	20	41	75	60.50	60.05	7.67	13	7
	ART3	20	41	70	57.00	56.25	7.93	8	12

Table 14 Descriptive statistics for SOT, SV, and PAC by ART level, sorted by high/low group membership

			N	**Mean**	**SD**	**SE**	**95% CI for mean**
SOT	ART1	Low	8	20.03	5.50	1.94	(15.44, 24.63)
		High	12	7.90	1.78	0.51	(6.77, 9.03)
	ART2	Low	12	19.59	6.82	1.97	(15.25, 23.92)
		High	8	7.40	2.14	0.76	(5.60, 9.19)
	ART3	Low	10	18.67	5.18	1.64	(14.96, 22.37)
		High	10	6.75	1.54	0.49	(5.65, 7.86)
SV	ART1	Low	8	0.41	0.05	0.02	(0.37, 0.45)
		High	12	0.59	0.08	0.02	(0.54, 0.64)
	ART2	Low	7	0.40	0.04	0.01	(0.37, 0.44)
		High	13	0.60	0.11	0.03	(0.54, 0.67)
	ART3	Low	12	0.38	0.11	0.03	(0.31, 0.45)
		High	8	0.67	0.09	0.03	(0.59, 0.75)
PAC	ART1	Low	10	50.10	7.42	2.34	(44.80, 55.41)
		High	10	62.60	4.93	1.56	(59.08, 66.12)
	ART2	Low	7	52.29	5.50	2.08	(47.20, 57.37)
		High	13	64.23	4.90	1.36	(61.27, 67.19)
	ART3	Low	12	51.25	5.56	1.61	(47.72, 54.78)
		High	8	63.75	3.85	1.36	(60.54, 66.97)

4.4.5.2.1 Route-Selection Task Evaluation

A 2-way, between-groups ANOVA revealed no significant interaction between SOT and ART on route-selection scores; however, there was a significant main effect of SOT on route-selection scores, $F(1,54) = 4.40$, $p = .041$, $\eta_p^2 = .08$ (see Fig. 40). Post hoc comparisons between high/low SOT groups within each ART level show that low-SOT individuals (those who performed better on the SOT) had

higher route-selection scores in each ART: ART1, $t(18) = –1.29$, $p = .214$, $d = 0.61$; ART2, $t(18) = –1.10$, $p = .287$, $d = 0.50$; and ART3, $t(18) = -1.24$, $p = .230$, $d = 0.56$. Although these post hoc analyses did not reach statistical analysis, they had medium-effect sizes.

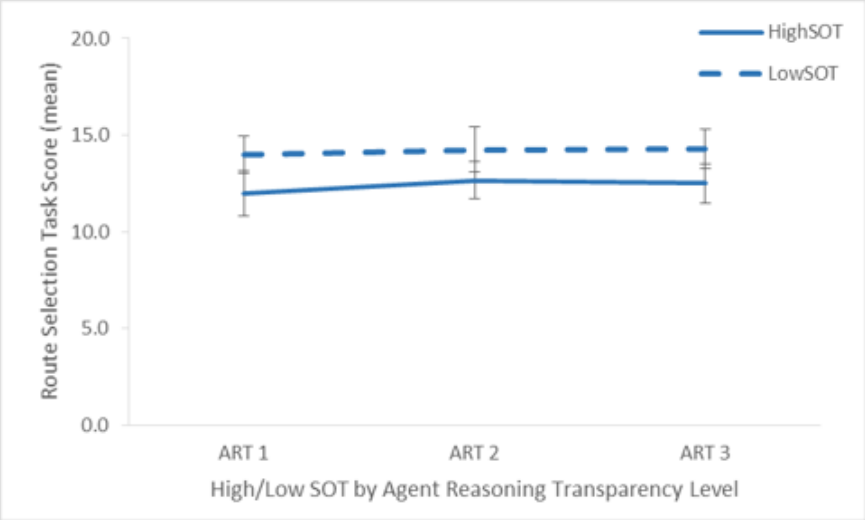

Fig. 40 Average route-selection scores by high/low SOT group membership across ART level; bars denote SE

A 2-way, between-groups ANOVA revealed no significant interaction between SV and ART on route-selection scores nor any significant main effect of SV on route-selection scores.

A 2-way, between-groups ANOVA revealed no significant interaction between PAC and ART on route-selection scores; however, there was a significant main effect of PAC on route-selection scores, $F(1,54) = 3.98$, $p = .051$, $\eta_p^2 = .07$ (see Fig. 41). Post hoc comparisons between high/low PAC groups within each ART level show that high-PAC individuals had higher route-selection scores in each ART: ART1, $t(18) = –1.18$, $p = .255$, $d = 0.53$; ART2, $t(18) = –0.74$, $p = .467$, $d = 0.34$; and ART3, $t(18) = –1.56$, $p = .137$, $d = 0.69$. Although these post hoc analyses did not reach statistical analysis, they had medium-effect sizes.

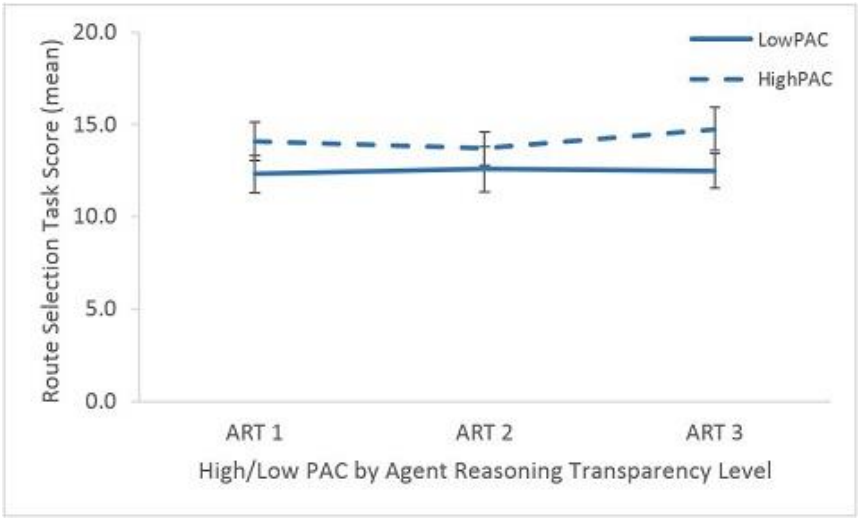

Fig. 41 Average route-selection scores by high/low PAC group membership across ART level; bars denote SE

4.4.5.2.2 SA1 Evaluation

Two-way, between-groups ANOVAs revealed no significant ART interaction among SOT, SV, or PAC on SA1 scores nor any significant main effect of SOT, SV, or PAC on SA1 scores across ART levels.

4.4.5.2.3 SA2 Evaluation

A 2-way, between-groups ANOVA revealed no significant interaction between SOT and ART on SA2 scores; however, there is a significant main effect of SOT on SA2 scores, $F(1,54) = 16.98$, $p < .001$, $\eta_p^2 = .24$ (see Fig. 42). Post hoc comparisons between high/low SOT groups within each ART level show that high-SOT and low-SOT individuals had similar SA2 scores in ART1; however, high-SOT participants had higher SA2 scores in ART2, $t(18) = -2.78$, $p = .012$, $d = 1.29$, and ART3, $t(18) = -3.09$, $p = .006$, $d = 1.42$. When agent reasoning was not available there was no significant difference in SA2 scores between high- and low-SOT persons. However, when agent reasoning was available participants who performed better on the SOT also had higher SA2 scores than their counterparts.

Two-way, between-groups ANOVAs revealed no significant interaction between SV or PAC and ART on SA2 scores nor any significant main effect of SV or PAC on SA2 scores across ART levels.

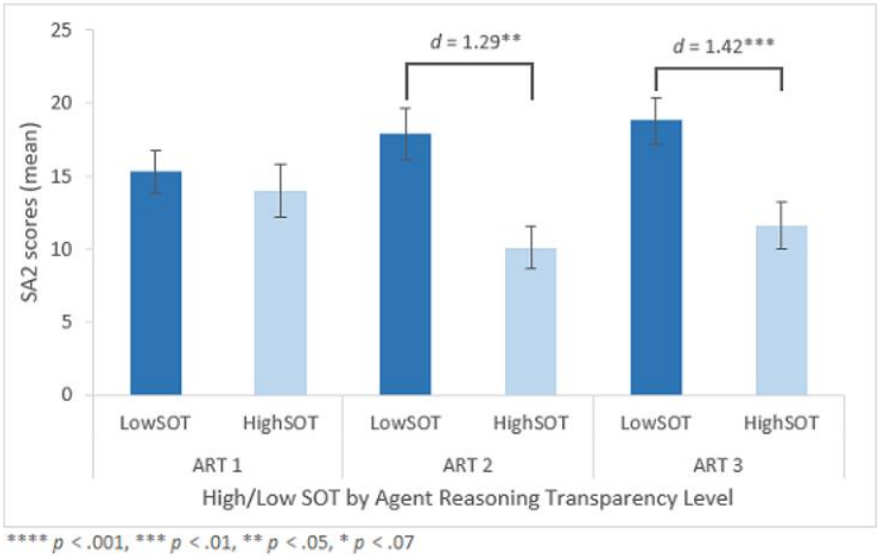

Fig. 42 Average SA2 scores by SOT high/low group membership sorted by ART level; bars denote SE

4.4.5.2.4 SA3 Evaluation

Two-way, between-groups ANOVAs revealed no significant ART interaction among SOT, SV, or PAC on SA3 scores nor any significant main effect of SOT, SV, or PAC on SA3 scores across ART levels.

4.4.5.3 WMC

Hypothesis 11: High-WMC individuals will have more correct rejects and higher SA2 and SA3 scores than low-WMC individuals.

The effects of WMC and ART level were evaluated via 2-way, between-groups ANOVAs, $\alpha = .05$. Post hoc t-tests within each ART compared performance differences between high/low group memberships. Descriptive statistics for WMC, as measured using the RSPAN test, are shown in Tables 25 and 26.

Table 25 Descriptive statistics for WMC by ART level

								Mdn split count	
	Group	**N**	**Min**	**Max**	**Mdn**	**Mean**	**SD**	**Hi**	**Lo**
WMC	Overall	60	10	54	31.00	31.47	12.06	31	29
	ART1	20	17	54	31.00	33.15	11.86	11	9
	ART2	20	11	54	32.50	31.10	13.75	11	9
	ART3	20	10	54	28.00	30.15	11.17	9	11

Table 26 Descriptive statistics for WMC by ART level, sorted by high/low group membership

			N	**Mean**	**SD**	**SE**	**95% CI for mean**
WMC	ART1	Low	9	22.11	3.55	1.18	(19.38, 24.84)
		High	11	42.18	7.59	2.29	(37.08, 47.28)
	ART2	Low	9	18.00	4.61	1.54	(14.46, 21.54)
		High	11	41.82	7.83	2.36	(36.56, 47.08)
	ART3	Low	11	22.09	5.65	1.70	(18.30, 25.88)
		High	9	40.00	7.62	2.54	(34.15, 45.85)

4.4.5.3.1 Correct Rejects

A 2-way, between-groups ANOVA revealed no significant interaction between WMC and ART on correct-rejection scores nor any significant main effect of WMC on correct-reject scores.

4.4.5.3.2 SA Scores

A 2-way, between-groups ANOVA revealed no significant interaction between WMC and ART on SA2 scores; however, there was a significant main effect of WMC on SA2 scores across ARTs, $F(1,54) = 8.33$, $p = .006$, $\eta_p^2 = .13$ (see Fig. 43). High-WMC participants had higher SA2 scores in all ART conditions—ART1, $t(18) = -2.25$, $p = .037$, $d = 1.01$; ART2, $t(18) = -2.28$, $p = .035$, $d = 1.02$; and ART3, $t(18) = -1.94$, $p = .359$, $d = 0.44$—than their low-WMC counterparts. Performance of the high-WMC group was consistent among ARTs, while the low-WMC participants' SA2 scores varied. This difference was greatest in ART2, where access to agent reasoning resulted in low-WMC participants having lower SA2 scores than in the no-reasoning condition, and smallest in ART3, where increased access to agent reasoning appears to have helped low-WMC participants' SA2 scores increase to almost that of their high-WMC counterparts.

There was no significant interaction between WMC and ART on SA3 scores nor any significant main effect of WMC on SA3 scores.

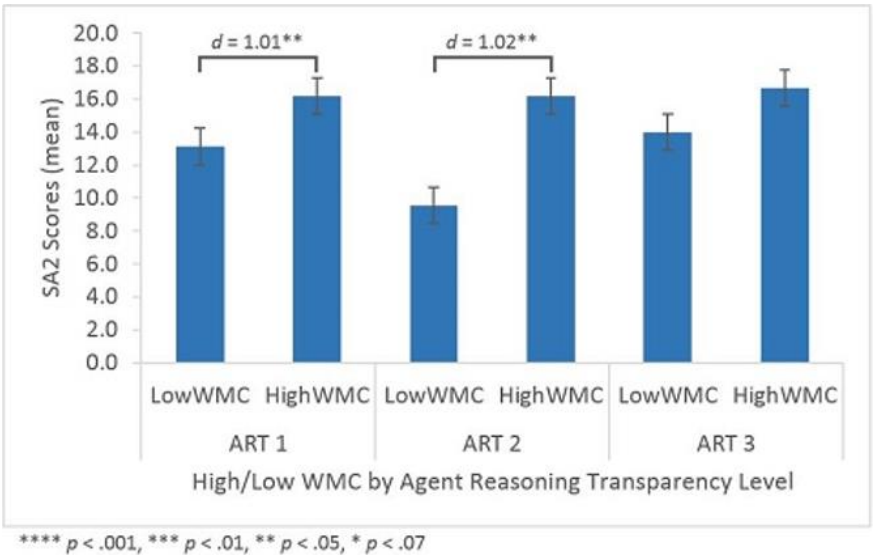

Fig. 43 Average SA2 scores by WMC high/low group membership sorted by ART level; bars denote SE

4.6 Discussion

The primary goal of this study was to examine how the transparency of an intelligent agent's reasoning in a high-information environment affected complacent behavior in a route-selection task. Participants supervised a 3-vehicle convoy as it traversed a simulated environment and rerouted the convoy when needed with the assistance of an intelligent agent, RoboLeader. Information regarding potential events along the preplanned route, together with communications from a commander confirming either the presence or absence of activity in the area, were provided to all participants. They received information about both their current route and the agent-recommended alternative route. When the convoy approached a potentially unsafe area, the intelligent agent would recommend rerouting the convoy. The agent recommendations were correct 66% of the time. The participant was required to recognize and correctly reject any incorrect suggestions. The secondary goal of this study was to examine how differing levels of agent transparency affected main-task and secondary-task performance, response time, workload, SA, trust, and system usability along with implications of ID factors such as spatial ability, WMC, PAC, and CP.

Each participant was assigned to a specific level of ART. The reasoning explained why the agent was making the recommendation and this differed among these levels. ART1 provided no reasoning information; RL notified that a change was recommended without explanation. The type of information the agent supplied varied slightly between ARTs 2 and 3. In ART2 the agent reasoning was simple statements of fact corresponding to the information icons that appeared on the map,

along with reasoning as to how the agent factored each piece of information into its final recommendation (e.g., Recommend revise convoy route: Potential IED (H[igh]), Potential Sniper (M[edium]), Dense Fog (L[ow]). In ART3 an additional piece of information was added, time of report, that conveyed when the agent had received the information leading to its recommendation (e.g., Recommend revise convoy route: Potential IED (H), TOR: 1 [hr]; Potential Sniper (M), TOR: 2; Dense Fog (L), TOR: 4). This additional information did not convey any confidence level or uncertainty but was designed to encourage the operator to actively evaluate the quality of the information rather than simply respond. Therefore, not only was access to agent reasoning examined, but the impact of the type of information the agent supplied was reviewed, as well.

Complacent behavior was investigated via primary (route-selection) task response at those decision points where the agent recommendation was incorrect, in the form of incorrect acceptances of the agent recommendation, an objective measure of errors of commission (Parasuraman et al. 2000). Access to agent reasoning was predicted to reduce the number of incorrect acceptances while an increase in ART was expected to increase incorrect acceptances. The trend in the data appeared to support this prediction even though the findings were not significant. While there was a slight decrease in the mean score for incorrect acceptances when ART was added, the highest mean score for incorrect acceptances was in ART3, when ART was highest. Response times for incorrect acceptances were longer than those for correct rejections in the ART condition, indicating these incorrect acceptances could be the result of errors in judgment rather than an indication of complacent behavior. However, in the condition with the highest amount of ART, not only are there more incorrect acceptances of the agent suggestion, but the decision times for these responses are no different from those for correct rejections. Considered together, this may indicate the combination of high information and increased access to agent reasoning could overwork the operator, resulting in an OOTL situation. Differences due to IDs support this notion, as individuals with higher WMC had fewer incorrect acceptances overall, demonstrating an ability to process more information more effectively than their counterparts. Additionally, individuals who scored low on complacency potential had fewer incorrect acceptances in the ART conditions. There was no difference in performance between high- and low-CP individuals in the information-only condition. However, when agent reasoning was transparent, low-CP individuals had more correct rejections than the high-CP individuals, and when ART was increased the difference in performance became more pronounced. The better performance of low-CP individuals could indicate either their willingness to engage with the agent rather than defer or their calibrated trust in the ability of the intelligent agent (Parasuraman and Manzey 2010).

As in EXP1, the operator received all information needed to route the convoy correctly without the agent's suggestion. While the addition of agent reasoning did result in fewer incorrect acceptances than in the no-reasoning condition, the difference was not significant. However, the small reduction in the number of incorrect acceptances considered with the increased response times does provide evidence that the addition of ART is effective at keeping the operator engaged in the task, even if the performance gains are small. In the highest reasoning-transparency condition, operators were also given information that could have seemed ambiguous and, as a result, the number of incorrect acceptances increased while the response times were unchanged from those for correct responses. Thus, the addition of information whose use is not clear created a situation that encouraged the operator to defer to the agent suggestion.

Performance on the route-selection task was evaluated via correct rejections and acceptances of the agent suggestion. An increased number of correct acceptances and rejections, as well as reduced decision times, were all indicative of improved performance. Route-selection performance was anticipated to improve with access to agent reasoning and then decline as access to agent reasoning increased. This hypothesis was not supported. Performance was unchanged in the ART conditions compared to the information-only condition. Decision times (overall and correct responses) were slightly longer in the ART conditions compared to the information-only condition, which is to be expected due to the additional processing required for the ART. However, decision times for incorrect responses did not follow this trend, with mean decision time in the most transparent agent reasoning condition being shortest of all conditions. This shortening of deliberation time could indicate complacent behavior is occurring in this condition.

CP, as evaluated using the Complacency Potential Rating Scale, and Spatial Orientation Test scores were found to be predictive of performance on the route-selection task, in that individuals with low CP and those with high SO ability were found to score higher on the route-selection task overall. There were also performance differences due to Perceived Attentional Control; individuals with higher PAC had better performance on the route-selection task in all ART conditions. When considered together, these findings support the notion that automation bias is, at least to some degree, an issue stemming from attention-resource issues (Parasuraman and Manzey 2010).

Participant trust in the agent was assessed objectively by evaluating incorrect rejections of the agent's suggestions and subjectively using the Usability and Trust Survey. As in EXP1, the objective measure of operator trust indicated no difference in trust due to ART. However, unlike EXP1, the subjective measures also indicated no difference in trust or perceived usability due to ART. The CP, as evaluated using

the CPRS, was found to be predictive of operator trust as evaluated via incorrect rejections and scores on the Usability and Trust Survey. Individuals with low CP were found to have fewer incorrect rejections of the agent recommendation overall and reported higher trust and usability of the agent than their high-CP counterparts. However, there was no difference in incorrect rejections, trust, or usability evaluations across ART conditions between high- and low-CP individuals, which indicates these findings were not affected by the presence (or lack thereof) of ART.

Participant workload was expected to increase as ART increased. However, this hypothesis was not supported. Workload was evaluated using the NASA-TLX and several ocular indices that have been shown to be informative as to cognitive workload. Global NASA-TLX scores decreased as ART increased, but such changes were not significant. Pupil diameter also decreased as ART increased, indicating overall cognitive workload decreased as ART increased. Participant PDia was larger in the information-only condition compared to the ART conditions, indicating the presence of ART reduced cognitive workload. This finding contradicts our stated hypothesis. Fixation Count and Fixation Duration did not differ significantly among the 3 ART levels, indicating no difference in cognitive workload.

Similar to global scores, Mental Demand and Physical Demand were greater in ART1 than in ARTs 2 or 3, suggesting the access to agent reasoning reduced cognitive workload. The ratings for NASA-TLX Temporal Demand and Effort were higher in ART1 than in either ART2 or 3, albeit not significantly different, which would support the MD ratings. Interestingly, participants also reported higher satisfaction in their Performance in ART2 than in ART3. Although participants reported greater MD in ART2 than in ART3, they also stayed more engaged in the task as indicated by their increased decision times for incorrect responses, resulting in higher performance ratings. Alternatively, the addition of the recency information in ART3 created an overwork condition for the operator, which encouraged complacent behavior. The combination of decreased satisfaction in their performance and reduced DTs for incorrect responses in ART3 could indicate an OOTL situation.

Situation Awareness scores were hypothesized to improve with access to agent reasoning—with the exceptions of SA1 and SA3 scores in ART3. In this study, SA1 scores evaluated how well the participant maintained a general awareness of their environment. The additional context gained by access to agent reasoning would make certain events and situations more salient, which in turn would lead to improved performance on the route-selection task (Hancock and Diaz 2002). However, increased access to agent transparency was expected to overwhelm the participant, leading to a decline in SA1 and SA3 scores. The hypotheses were not

supported; SA scores did not improve with access to agent reasoning nor did they vary across ART levels. In a high-information environment, access to agent reasoning does not appear to affect operator SA. These results offer limited support for EXP1 findings in which access to agent reasoning does little to improve SA.

While there were no differences in SA because of agent reasoning access, there were notable distinctions in SA scores for several ID factors. Low-CP individuals overall had higher SA1 scores than their high-CP counterparts in all ART levels, which could be due to reduced trust in the agent encouraging them to monitor their surroundings more carefully (Pop, Shrewsbury, and Durso 2015)—in effect, supervising the agent. High-WMC individuals had higher SA2 scores across all ART levels than their low-WMC counterparts, demonstrating their improved ability to assimilate the information from various sources into a coherent understanding (Wickens and Holland 2000). Low-WMC individuals' SA2 scores were lowest in ART2, which could indicate the access to agent reasoning overtasked them. High spatial orientation (SO) individuals had higher SA2 scores when ART was available than their low-SO counterparts. While both groups had similar SA2 scores in the absence of agent reasoning, when access to agent reasoning became available the high-SO individuals' SA2 scores improved while the low-SO individuals' SA2 scores decreased. Gugerty and Brooks (2004) found that high-SO individuals were better able to overlook slight disparities in reference-frame alignments. This ability could explain why high-SO individuals appear to have increased skill when combining information from several sources (one of which being a map of the area) into a comprehensive understanding of the environment surrounding the convoy's route.

Access to agent reasoning appeared to have little influence on performance in the target-detection task. The number of targets detected in ART3 was significantly lower than the other 2 conditions, indicating that increased ART interfered with this task. However, access to agent reasoning had no effect on the number of FAs reported. The SDT was used to evaluate whether access to agent reasoning had any effect on sensitivity or selection criteria. There was no significant difference in either sensitivity to targets, assessed as *d'*, or selection criteria, assessed as Beta, across ART levels. In an information-rich environment, ART appears to have no effect on sensitivity to targets or target-selection criteria.

As in EXP1, a potential limitation of this work could be the added time information in ART3. Participants in that agent reasoning condition were instructed that the time reflected when the agent received the information upon which it based its recommendation; however, they were not instructed how they should use that information in their deliberations. Thus, this information could have appeared

ambiguous to the participants and there could be variability in how they factored this information into their decision based upon their personal experience.

4.7 Conclusion

The findings of the present study are important for the design of intelligent recommender and decision-aid systems. Keeping the operator engaged and in the loop is important for reducing complacency that could allow lapses in system reliability to go unnoticed. To that end, we examined how agent reasoning transparency affected complacent behavior, as well as task performance, workload, and trust when the operator had complete information about their task environment.

Access to agent reasoning was found to have little effect on complacent behavior when the operator has complete information about the task environment. However, the addition of information that created ambiguity for the operator appeared to encourage complacency, as indicated by reduced performance and shorter DTs. ART did not increase overall workload, which agrees with previous studies (Mercado et al. 2015), and operators reported higher satisfaction with their performance and reduced mental demand. Contrary to findings previously reported by Helldin et al. (2014) and Mercado et al. (2015), access to agent reasoning did not improve operators' secondary-task performance, SA, or operator trust. However, this access did not have a negative effect until transparency increased to such a level as to include ambiguous information, thus encouraging complacency. As such, these findings suggest that when the operator has complete information regarding their task environment, access to agent reasoning may be beneficial but not dramatically so. However, ART that includes ambiguous information does have negative effects; as such, the amount of transparency and the type of information conveyed to the operator should be carefully considered.

5. Comparison of EXP1 and EXP2

5.1 Objective

Results from Experiments 1 and 2 were compared to evaluate how differences in the level of information available to the operator interacted with access to the agents' reasoning and uncertainty information. In ART1, the only difference between EXP1 and EXP2 was the amount of information the participant received via the map icons. In ARTs 2 and 3, ART was similar between the 2 experiments in that participants were shown the agent reasoning equating to each map icon; there were simply more icons in EXP2 to explain. However, in EXP2 participants were also told how the agent factored each piece of information into its

recommendation via the weighing factor; thus, there was a slight increase in ART in ARTs 2 and 3 compared to EXP1.

5.2 Stated Hypotheses

5.2.1 Complacent Behavior, Primary Task Performance, Trust in the Agent

We hypothesize that complacent behavior in the high-information environment (EXP2) will be lower than in the low-information environment (EXP1) in the absence of agent reasoning (ART1). The additional information should help the participant successfully maneuver their environment more safely. The presence of agent reasoning (ART2) will assist the operator in understanding the additional environmental information, resulting in reduced incorrect acceptances in the high-information environment (EXP2) from the low-information environment (EXP1). However, the increase in agent reasoning transparency (ART3) will overload the operator; as a result, incorrect acceptances will be greater in the high-information environment (EXP2) than in the low-information environment (EXP1).

Hypothesis 1: Incorrect acceptances will be lower in EXP2 than in EXP1 in ART1 (EXP1 > EXP2), as the additional environmental information will reduce the operator's dependency on the agent's recommendations. In ART2, incorrect acceptances will be lower in EXP2 than in EXP1 due to the presence of agent reasoning (EXP1 > EXP2). In ART3, incorrect acceptances will be higher in EXP2 than in EXP1 (EXP1 < EXP2) due to overloading the operator with information.

Hypothesis 2: Performance (number of correct rejections and acceptances) on the route-selection task in EXP2, compared to EXP1, will be

- Lower in ART1 due to increased environmental information without access to agent reasoning (EXP1 > EXP2).
- Greater in ART2 due to access to agent reasoning, (EXP1 < EXP2).
- Lower in ART3 due to information overload as a result of the increase in transparency of the agent reasoning, which included ambiguous information (EXP1 > EXP2).

In all conditions, time to decide on the route-selection task will be higher in EXP2 than EXP1 (EXP1 < EXP2).

Hypothesis 3: Operator trust in the agent will be greater in EXP2 than in EXP1 for ARTs 1 and 2 (EXP1 < EXP2). However, operator trust will be lower in EXP2 than in EXP1 for ART3 (EXP1 > EXP2).

5.2.2 Workload

Hypothesis 4: Operator perceived workload will be greater in EXP2 than in EXP1 for all ARTs (EXP1 < EXP2). Inferred measures of workload (i.e., PDia, FC, and FD) will also show increased workload.

5.2.3 SA

Hypothesis 5: The increased environmental information will result in lower SA scores in EXP2 than in EXP1 in ARTs 1 and 3 (EXP1 > EXP2) for SA1 and SA3 measures. SA2 scores will be higher in EXP2 than in EXP1 in ARTs 1 and 2; however, they will be lower in ART3:

- SA1: ARTs 1, 2 and 3: EXP1 > EXP2
- SA2: ARTs 1 and 2: EXP1 < EXP2; ART3: EXP1 > EXP2.
- SA3: ARTs 1, 2 and 3: EXP1 > EXP2

5.2.4 Target-Detection Task Performance

Hypothesis 6: Performance in the target-detection task, in both targets detected and FAs, will be worse in EXP2 than in EXP1 in all ARTs due to information overload.

- Number of targets detected: EXP1 > EXP2
- False alarms: EXP1 < EXP2.

5.3 Results

Data were examined using independent samples t-tests ($\alpha = .05$) within each ART level between EXP1 and EXP2. Equal variances between groups were not assumed. Specifically, ART1 was compared to ART1, ART2 to ART2, and ART3 to ART3 for each measure of interest. Means, SD, SE, and 95% CI are reported for each measure.

5.3.1 Complacent Behavior, Primary Task Performance, Trust in the Agent

5.3.1.1 Complacent-Behavior Evaluation

Hypothesis 1: Incorrect acceptances will be lower in EXP2 than in EXP1 in ART1 (EXP1 > EXP2) as the additional environmental information will reduce the operator's dependency on the agent's recommendations. In ART2, incorrect acceptances will be lower in EXP2 than in EXP1 due to the presence of agent

reasoning (EXP1 > EXP2). In ART3, incorrect acceptances will be higher in EXP2 than in EXP1 (EXP1 < EXP2) due to overloading of the operator with information.

Descriptive statistics for incorrect acceptances and EXP1–EXP2 t-test results are shown in Table 27.

Table 27 Descriptive statistics for incorrect acceptances sorted by experiment for each ART level, and t-test results for between-experiment comparisons

		N	Mean	SD	SE	95% CI for mean	*df*	*t*	*p*	Cohen's *d*
ART1	EXP1	20	3.25	2.27	0.51	(2.19, 4.31)	27.6	4.03	<.001	1.35
	EXP2	20	0.98	1.11	0.25	(0.46, 1.49)				
ART2	EXP1	20	1.15	1.31	0.29	(0.54, 1.76)	33.9	0.70	.488	0.23
	EXP2	20	0.90	0.91	0.20	(0.47, 1.33)				
ART3	EXP1	20	2.65	2.32	0.52	(1.56, 3.74)	34.2	1.81	.079	0.58
	EXP2	20	1.50	1.64	0.37	(0.73, 2.27)				

Evaluating incorrect acceptances between experiments shows that, overall, more incorrect acceptances occurred in EXP1 than EXP2 (see Fig. 44). There was a significant correlation between experiment and the number of incorrect acceptances regardless of ART, $r = –.26$, $p = .013$. In ART1, which had no agent reasoning available for the operator, there were fewer incorrect acceptances in EXP2 than EXP1. This supports the hypothesis and is strong evidence that operator knowledge of the task environment can reduce complacent behavior even in the absence of agent reasoning. As predicted, incorrect acceptances were also lower in EXP2 than in EXP1 in ART2. However, this result was not statistically significant. It was expected that the increased ART in ART3 would overwhelm the operator in EXP2, resulting in higher incorrect acceptances. However, this was not the case. Although EXP2 mean scores in ART3 were greater than those in ARTs 1 or 2, indicating the increased transparency was not without its cost, scores were significantly lower than in EXP1. Overall, these findings are evidence of the importance of information in addition to ART for reducing the complacent behavior.

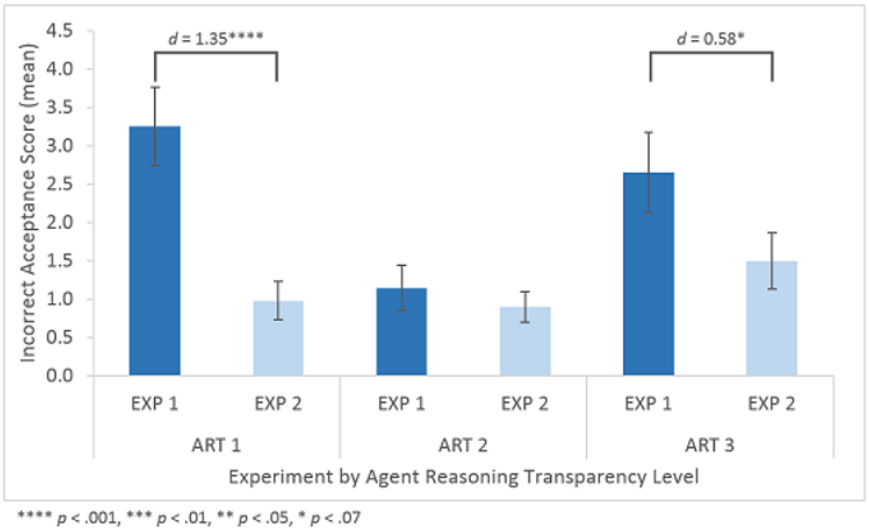

Fig. 44 Average incorrect acceptances by experiment for each ART level; bars denote SE

Participants' scores were further analyzed by comparing the number of participants who had no incorrect acceptances, by ART level, between EXP1 and EXP2 (see Fig. 45). Chi-square analysis found a significant difference in the number of participants with no incorrect acceptances in ART1, $X^2(6) = 15.26$, $p = .018$, Cramer's $V = .618$, but no difference in ART2 or ART3. In ART1, the increased information in EXP2 appeared to improve the participants' ability to discern when the agent was incorrect compared to EXP1. However, the addition of agent reasoning in ARTs 2 and 3 appeared to improve EXP1 participants' ability to discern when the agent was incorrect to the same degree as in EXP2. When participants did incorrectly accept the agent's recommendation, more participants made incorrect acceptances in EXP1 ($n = 43$) than in EXP2 ($n = 35$) across all ARTs. Of these, 89% of participants in EXP2 scored less than 50% on incorrect acceptances, compared to 51% of those in EXP1.

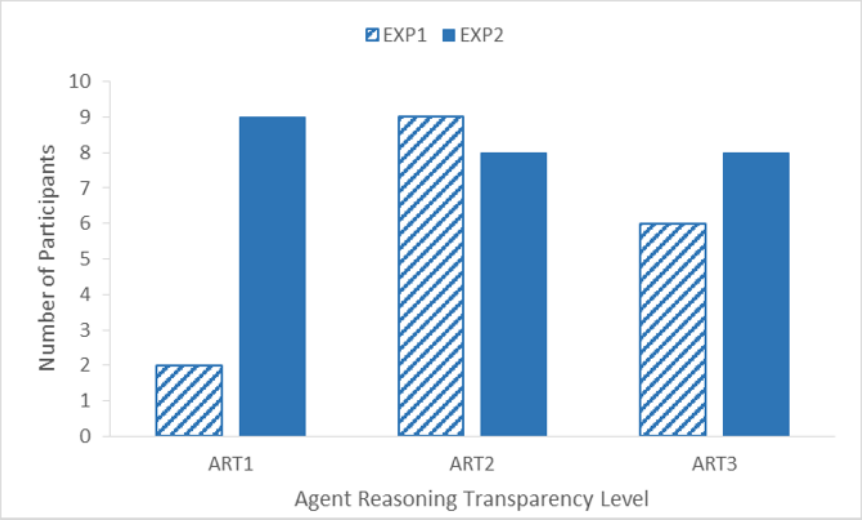

Fig. 45 Between-experiment comparisons of the number of participants who had no incorrect acceptances in each ART level

Decision time for responses on the route-selection task at those locations where the agent recommendation was incorrect was evaluated. It was hypothesized that DT would increase as ART increased, and DTs in EXP2 would be longer than those in EXP1, as participants should require additional time to process the extra information. Thus, reduced time could indicate less time spent in deliberation, which could be an indication of complacent behavior. Descriptive statistics for DTs and EXP1–EXP2 t-test results are shown in Table 28.

Table 28 Descriptive statistics for average DT at those locations where the agent recommendation is incorrect sorted by experiment for each ART level, and t-test results for between-experiment comparisons

		N	Mean	SD	SE	95% CI for mean	*df*	*t*	*p*	Cohen's *d*
ART1	EXP1	20	7.63	3.10	0.69	(6.18, 9.08)	36.9	–3.27	.002	1.04
	EXP2	20	11.14	3.68	0.82	(9.42, 12.87)				
ART2	EXP1	20	7.20	2.77	0.62	(5.91, 8.50)	36.7	–4.43	<.001	1.41
	EXP2	20	11.51	3.35	0.75	(9.94, 13.08)				
ART3	EXP1	20	7.89	3.01	0.67	(6.48, 9.30)	35.5	–3.97	<.001	1.27
	EXP2	20	12.30	3.96	0.89	(10.45, 14.16)				

Evaluating DTs at those locations where the agent recommendation was incorrect between experiments shows that participants took longer deliberating in EXP2 than EXP1 (see Fig. 46) across all ARTs, which supports the hypothesis. This difference was smallest in ART1 (ΔM = 3.52) and larger when ART was present (ART2, ΔM = 4.31; ART3, ΔM = 4.42). Participants took longer to reach their decisions in EXP2 than in EXP1, most likely due to the increased environmental information and increased agent reasoning.

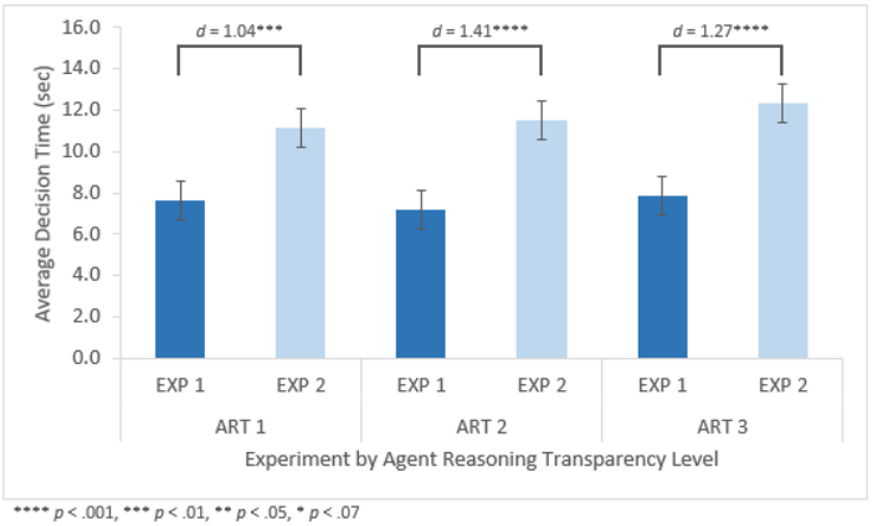

Fig. 46 Average DT in seconds for participant responses at decision points where the agent recommendation was incorrect sorted by experiment for each ART level; bars denote SE

It is interesting that in ART3, when ART was at its highest, DT was the roughly the same as in ART2. In order to understand this lack of difference, DTs were also evaluated by correct/incorrect responses. In Table 29, DTs are sorted by correct rejections, incorrect acceptances, and experiment for each ART level; further, t-test results are included for between-experiment comparisons.

Table 29 Descriptive statistics for DTs (in seconds) for participant responses at decision points where the agent recommendation was incorrect

			N	Mean	SD	SE	*df*	*t*	*p*	Cohen's *d*
Correct rejections	ART1	EXP1	14	8.96	8.69	2.32	32.0	–0.98	.337	0.34
		EXP2	20	11.15	4.25	0.95				
	ART2	EXP1	20	7.49	3.17	0.71	38.0	–3.73	.001	1.18
		EXP2	20	11.25	3.19	0.71				
	ART3	EXP1	18	8.14	3.47	0.82	36.0	–3.36	.002	1.12
		EXP2	20	12.94	5.09	1.14				
Incorrect acceptances	ART1	EXP1	18	8.72	4.88	1.15	27.0	–1.73	.096	0.65
		EXP2	11	12.17	5.76	1.74				
	ART2	EXP1	11	6.09	1.76	0.53	14.6	–5.91	<.001	2.65
		EXP2	12	14.37	4.49	1.30				
	ART3	EXP1	14	8.94	5.27	1.41	24.0	–2.01	.056	0.82
		EXP2	12	15.70	11.23	3.24				

Response times for both correct rejections and incorrect acceptances were significantly longer in EXP2 than EXP1 in all ARTs. However, the differences in response times between EXP1 and EXP2 were greater for the incorrect responses than the associated correct responses in each ART (see Fig. 47). There was no significant difference in response times between experiments for the notification-only condition, indicating the increase in information alone did not

result in an associated increase in DT, regardless of correct or incorrect status. Considered along with the reduced number of incorrect acceptances in EXP2, this could be evidence that information alone appears to be effective at mitigating complacent behavior. For correct rejections, differences in response time for the agent reasoning conditions were similar but longer than the response time for the notification-only condition. Response times for incorrect acceptances were considerably longer than those for correct rejections in the same ARTs, which could be evidence the incorrect responses were due to difficulty integrating all of the available information. In ART3 the difference in response time for incorrect acceptances is considerably longer than that for correct rejections and not significantly different between the 2 experiments. This is mainly due to the increased variability of response times in EXP2 in this ART level. The increased variability could indicate that while some participants erred due to difficulty in assimilating the information, others were exhibiting complacent behavior.

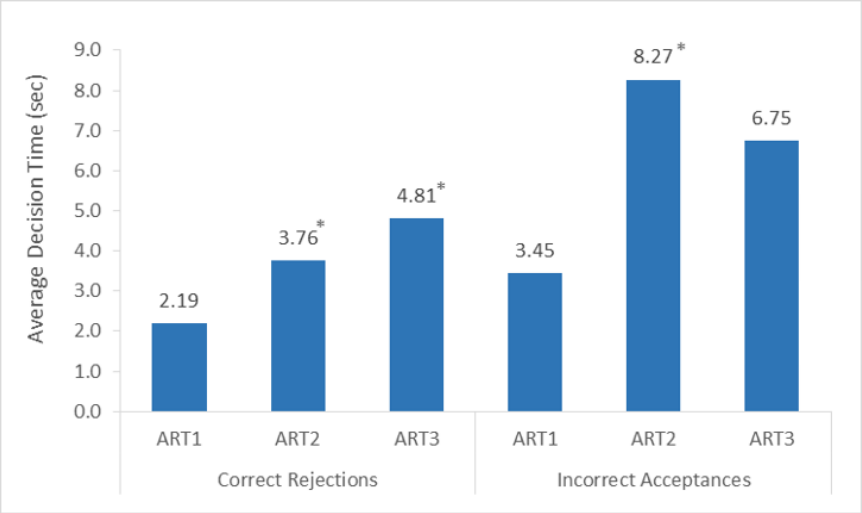

Fig. 47 Differences in mean DTs (EXP2–EXP1) for average DTs (in seconds) for correct rejections and incorrect acceptances, sorted by ART level; asterisk (*) denotes significant difference between experiments

5.3.1.2 Route-Selection Task Performance

Hypothesis 2: Performance (number of correct rejects and accepts) on the route-selection task in EXP2, compared to EXP1, will be

- Lower in ART1, due to increased environmental information without access to agent reasoning (EXP1 > EXP2).
- Greater in ART2, due to access to agent reasoning, (EXP1 < EXP2).

- Lower in ART3, due to information overload as a result of the increase in transparency of the agent reasoning, which included ambiguous information (EXP1 > EXP2).

In all conditions, time to decide on the route-selection task will be higher in EXP2 than EXP1 (EXP1 < EXP2).

Descriptive statistics for route-selection task scores and EXP1–EXP2 t-test results are shown in Table 30.

Table 30 Descriptive statistics for route-selection task scores sorted by experiment for each ART level, and t-test results for between-experiment comparisons

		N	Mean	SD	SE	95% CI for mean	*df*	*t*	*p*	Cohen's *d*
ART1	EXP1	20	14.10	2.59	0.58	(12.89, 15.31)	35.2	0.93	.358	0.30
	EXP2	20	13.20	3.46	0.77	(11.58, 14.82)				
ART2	EXP1	20	15.90	1.80	0.40	(15.06, 16.74)	30.1	3.18	.003	1.04
	EXP2	20	13.30	3.18	0.71	(11.81, 14.79)				
ART3	EXP1	20	14.70	2.81	0.63	(13.38, 16.02)	37.1	1.35	.187	0.43
	EXP2	20	13.40	3.28	0.73	(11.86, 14.94)				

Evaluating route-selection scores between experiments makes evident that, overall, scores were higher in EXP1 than in EXP2 (see Fig. 48), although this difference was only significant in ART2. In ART1, which had no agent reasoning available for the operator, and ART3, which had the greatest access to agent reasoning, route-selection scores were essentially the same between the 2 experiments. Increasing the amount of information available to the operator did not improve overall performance on the primary task as predicted, nor did performance improve when agent reasoning transparency was at its highest level. This is evidence that too much access to agent reasoning can have a similar effect on performance as too little. Results in ART2 are contrary to the predicted direction, where performance in EXP2 was expected to be greater than in EXP1. Instead, route-selection scores were significantly higher in EXP1 than in EXP2. These results indicate the combination of high environmental information and access to agent reasoning can have a detrimental effect on task performance.

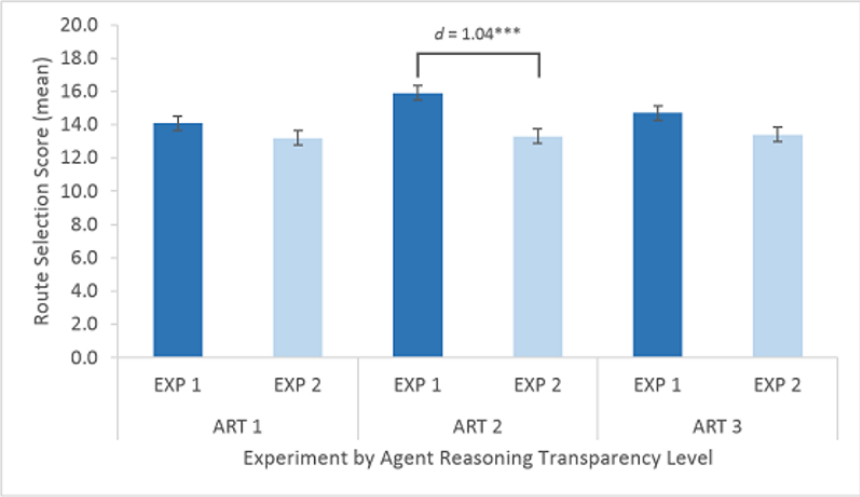

Fig. 48 Average route-selection task score by experiment for each ART level; bars denote SE

Participant performance was also evaluated via response time on the route-selection task. Descriptive statistics for overall DTs and EXP1–EXP2 t-test results are shown in Table 31.

Table 31 Descriptive statistics for overall DTs (in seconds) for the route-selection task sorted by experiment for each ART level, and t-test results for between-experiment comparisons

		N	Mean	SD	SE	95% CI for mean	*df*	*t*	*p*	Cohen's *d*
ART1	EXP1	20	7.64	3.60	0.81	(5.95, 9.32)	37.0	–3.06	.004	0.97
	EXP2	20	10.86	3.04	0.68	(9.44, 12.82)				
ART2	EXP1	20	7.51	3.36	0.75	(5.93, 9.08)	37.7	–4.92	<.001	1.56
	EXP2	20	12.53	3.09	0.69	(11.08, 13.97)				
ART3	EXP1	20	8.14	3.62	0.81	(6.46, 9.84)	34.9	–3.21	.003	1.03
	EXP2	20	12.52	4.91	1.10	(10.22, 14.81)				

Overall DT on the route-selection task was hypothesized to be longer in EXP2 than in EXP1 and the findings support the hypothesis. Comparing DTs between experiments shows that times were significantly longer in EXP2 than in EXP1 (see Fig. 49). This difference was smallest in ART1 (ΔM = 3.22) and larger when ART was present (ART2, ΔM = 5.02; ART3, ΔM = 4.38). Participants took longer to reach their decisions in EXP2 than in EXP1, most likely due to the increased environmental information and increased agent reasoning. It is interesting that in ART3 when ART was at its highest, DT was the same as in ART2. In order to understand this lack of difference, DTs were also evaluated by correct/incorrect responses (see Table 32).

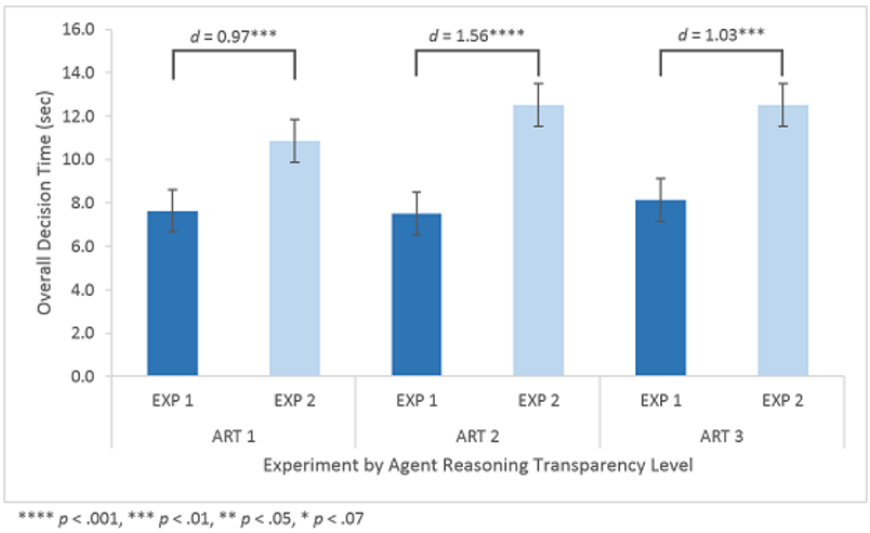

Fig. 49 Average route-selection task score by experiment for each ART level; bars denote SE

Table 32 Descriptive statistics for DTs (in seconds) for the route-selection task sorted by correct and incorrect responses and experiment for each ART level, and t-test results for between-experiment comparisons

			N	Mean	SD	SE	*df*	*t*	*p*	Cohen's *d*
Correct rejections	ART1	EXP1	20	7.52	3.50	0.78	38.0	–2.80	.008	0.89
		EXP2	20	10.32	2.79	0.62				
	ART2	EXP1	20	7.42	3.37	0.75	38.0	–4.23	<.001	1.34
		EXP2	20	11.95	3.40	0.76				
	ART3	EXP1	20	7.98	3.33	0.74	38.0	–3.42	.002	1.04
		EXP2	20	12.10	4.60	1.03				
Incorrect acceptances	ART1	EXP1	18	8.85	5.38	1.27	36.0	–2.40	.022	0.78
		EXP2	20	13.06	5.39	1.21				
	ART2	EXP1	17	8.44	4.20	1.02	34.0	–4.67	<.001	1.57
		EXP2	19	15.58	4.89	1.12				
	ART3	EXP1	14	9.16	5.20	1.39	29.0	–2.16	.039	0.82
		EXP2	17	14.77	8.46	2.05				

Response times for both correct and incorrect responses were significantly longer in EXP2 than EXP1 in all ARTs. However, the differences in response times between EXP1 and EXP2 were greater for the incorrect responses than the associated correct responses in each ART (see Fig. 50). For correct responses, the difference in response time for the agent reasoning conditions was similar but longer than the response time for the notification-only condition. Response times for incorrect responses were longer than those for correct responses in the same ARTs, which could be evidence the incorrect responses were due to difficulty integrating all of the available information. The reduced route-selection score along with the increased DTs in ART2 supports this notion. However, if this were the

case, the difference in response times for incorrect responses in ART3 would be at least as long as that in ART2; instead, it is shorter, and there is no difference in route-selection task scores between experiments in ART3. This reduction in response time may indicate some participants exhibited complacent behavior in the highest ART.

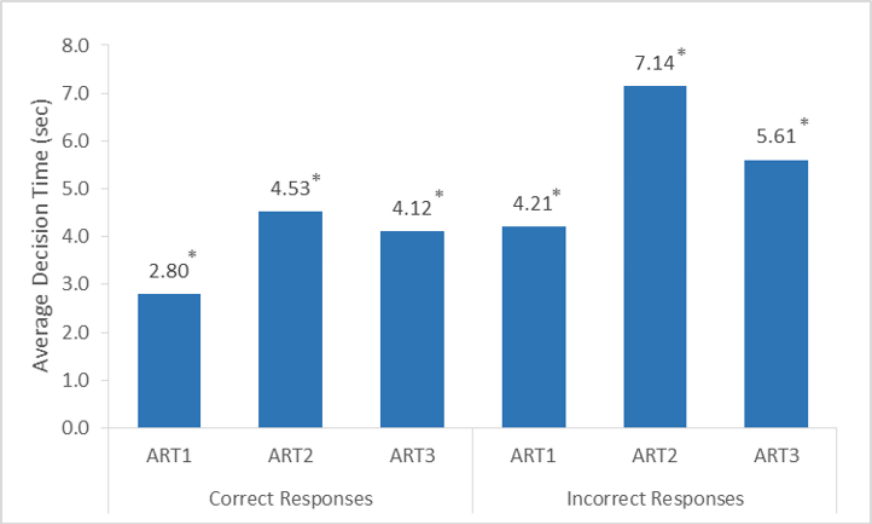

Fig. 50 Differences in mean DTs (EXP2–EXP1) for average DTs (in seconds) for correct and incorrect responses sorted by ART level; asterisk denotes significant difference between experiments

5.3.1.3 Operator-Trust Evaluation

Hypothesis 3: Operator trust in the agent will be greater in EXP2 than in EXP1 for ARTs 1 and 2 (EXP1 < EXP2). However, operator trust will be lower in EXP2 than in EXP1 for ART3 (EXP1 > EXP2).

Descriptive statistics for incorrect rejections and EXP1–EXP2 t-test results are shown in Table 33.

Table 33 Descriptive statistics for incorrect rejections sorted by experiment for each ART level, and t-test results for between-experiment comparisons

		N	Mean	SD	SE	95% CI for mean	*df*	*t*	*p*	Cohen's *d*
ART1	EXP1	20	0.75	1.14	0.26	(0.19, 1.26)	23.0	–3.68	<.001	1.31
	EXP2	20	3.75	3.49	0.78	(2.12, 5.39)				
ART2	EXP1	20	0.93	0.77	0.17	(0.57, 1.28)	21.9	–4.48	<.001	1.63
	EXP2	20	3.80	2.76	0.62	(2.51, 5.09)				
ART3	EXP1	20	0.34	0.54	0.12	(0.08, 0.59)	20.2	–4.00	<.001	1.54
	EXP2	20	3.10	3.04	0.68	(1.68, 4.52)				

Incorrect rejections of the agent recommendation at those locations where the agent recommendation was correct were evaluated as indicative of operator trust. There

were significantly more incorrect rejections in EXP2 than in EXP1 in all ARTs (see Fig. 51). Incorrect rejections in ARTs 1 and 2 were expected to be lower in EXP2 than in EXP1; as such, these findings are contrary to the stated hypothesis. Incorrect rejections in ART3 were expected to be higher in EXP2 than in EXP1 due to the combination of the high-information environment and increased access to ART, and this was supported. Across all ARTs, more participants had no incorrect rejections in EXP1 (33 out of 60) than in EXP2 (11 out of 60). The increased number of incorrect rejections in EXP2 is most likely due to the increase in task-environment information, which was consistent across ARTs.

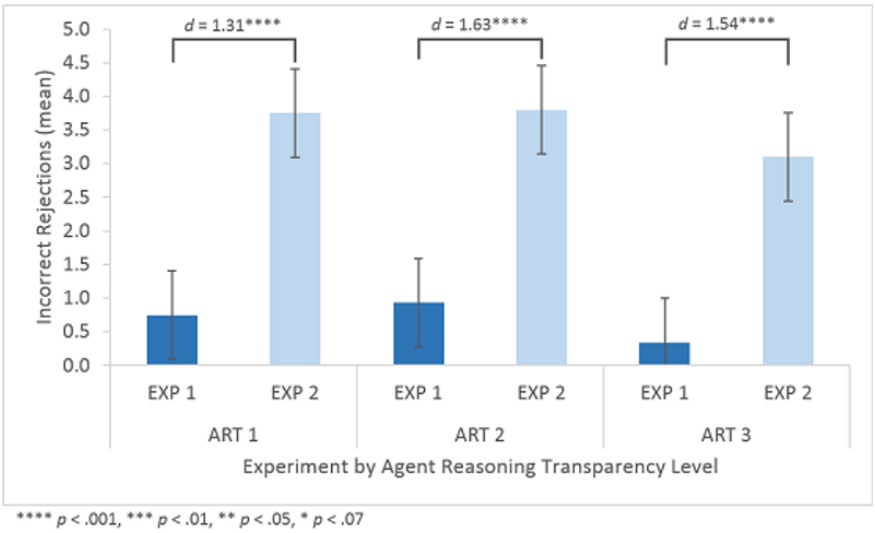

Fig. 51 Average number of incorrect rejections of agent recommendations by experiment for each ART level; bars denote SE

The DT on the route-selection task for the locations where the agent recommendation was correct was also compared between experiments. It was hypothesized that DT would increase as ART increased and DTs in EXP2 would be longer than those in EXP1 as participants should require additional time to process the extra information. Descriptive statistics for DTs and EXP1–EXP2 t-test results are shown in Table 34.

Table 34 Descriptive statistics for average DT at those locations where the agent recommendation is correct sorted by experiment for each ART level, and t-test results for between-experiment comparisons

		N	Mean	SD	SE	95% CI for mean	*df*	*t*	*p*	Cohen's *d*
ART1	EXP1	20	7.55	3.77	0.84	(5.79, 9.32)	35.8	–2.91	.006	0.93
	EXP2	20	10.65	2.92	0.65	(9.29, 12.02)				
ART2	EXP1	20	7.66	3.75	0.84	(5.90, 9.41)	38.0	–4.59	<.001	1.45
	EXP2	20	13.03	3.67	0.82	(11.32, 14.75)				
ART3	EXP1	20	8.07	3.60	0.80	(6.39, 9.76)	36.1	–3.12	.004	0.99
	EXP2	20	12.12	4.54	1.02	(9.99, 14.24)				

Evaluating DTs at those locations where the agent recommendation was correct between experiments makes evident that participants took longer deliberating in EXP2 than EXP1 (see Fig. 52) across all ARTs, which supports the hypothesis. This difference was smallest in ART1 (ΔM = 3.10) and larger when ART was present (ART2, ΔM = 5.38; ART3, ΔM = 4.04). Participants took longer to reach their decisions in EXP2 than in EXP1, most likely due to the increased environmental information.

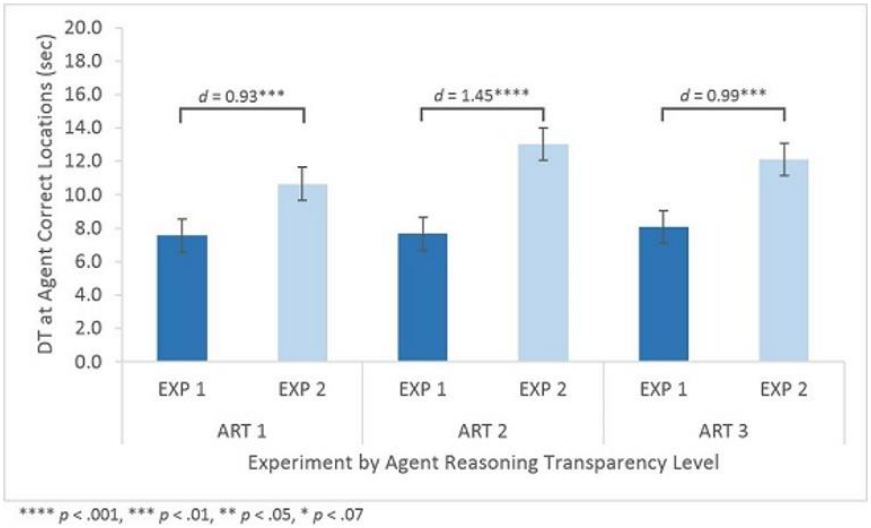

Fig. 52 Average DTs (in seconds) for operator responses at decision locations where the agent recommendation was correct sorted by experiment for each ART level; bars denote SE

DTs were also evaluated by correct/incorrect responses. In Table 35, DTs are sorted by correct acceptances, incorrect rejections, and experiment for each ART level. The table also shows t-test results for between-experiment comparisons.

Table 35 Descriptive statistics for DTs (in seconds) for participant responses at decision points where the agent recommendation was correct

			N	Mean	SD	SE	*df*	*t*	*p*	Cohen's *d*
Correct rejections	ART1	EXP1	20	8.21	5.82	1.30	38.0	–1.15	.256	0.38
		EXP2	20	9.89	2.91	0.65				
	ART2	EXP1	20	7.53	3.75	0.84	38.0	–3.79	.001	1.20
		EXP2	20	12.35	4.28	0.96				
	ART3	EXP1	20	8.04	3.59	0.80	38.0	–2.89	.006	0.93
		EXP2	20	12.10	5.14	1.15				
Incorrect acceptances	ART1	EXP1	7	10.79	9.82	3.71	21.0	–0.77	.448	0.32
		EXP2	16	13.26	5.57	1.39				
	ART2	EXP1	14	9.69	4.57	1.22	30.0	–3.54	.001	1.28
		EXP2	18	15.95	5.24	1.24				
	ART3	EXP1	6	9.62	4.59	1.88	19.0	–2.21	.242	0.64
		EXP2	15	13.20	6.62	1.71				

Response times for both correct acceptances and incorrect rejections were longer in EXP2 than EXP1 in all ARTs (see Fig. 53). There was no significant difference in response times between experiments for the notification-only condition (ART1), indicating the increase in information alone did not result in an associated increase in DT regardless of correct or incorrect response status. DTs in ART2 were significantly longer in EXP2 than in EXP1 regardless of correct or incorrect response status. This could indicate more-distrustful behavior, the participant's level of engagement with the agent, or difficulty integrating the information. However, it is likely the large increase in DT for EXP2 for incorrect rejections is an indication of difficulty integrating the available information.

In ART3, DTs for incorrect rejections were shorter than those for correct acceptances. This difference was significant for correct acceptances. However, there was no significant difference in DTs for incorrect rejections even though there were considerably more incorrect rejections in EXP2 than in EXP1. This could be an indication the incorrect rejections in ART3 were due to an overwork situation rather than difficulty integrating information (i.e., complacent behavior or overtrust).

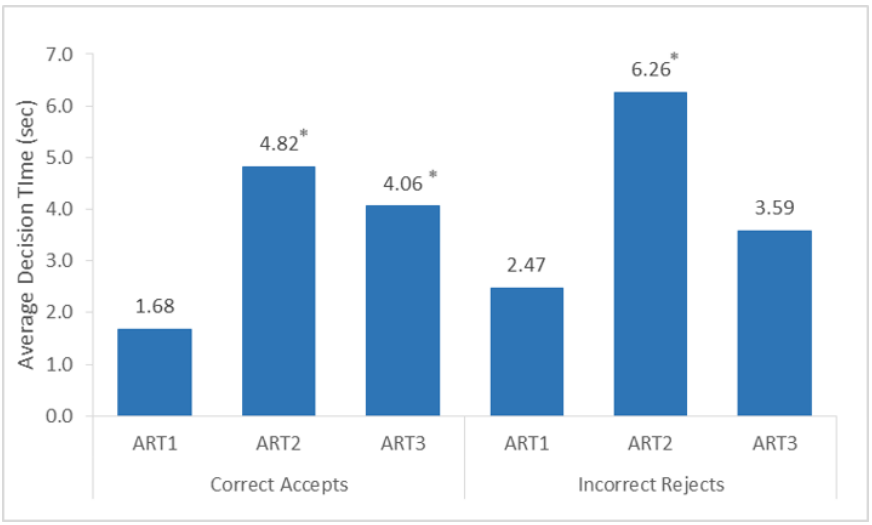

Fig. 53 Differences in mean DTs (EXP2–EXP1) for average DTs (in seconds) for correct acceptances and incorrect rejections sorted by ART level; asterisk denotes significant difference between experiments

Usability and Trust Survey results were also compared between experiments. Descriptive statistics for Usability and Trust Survey scores and EXP1–EXP2 t-test results are shown in Table 36.

Table 36 Descriptive statistics for Usability and Trust Survey score sorted by experiment for each ART level, and t-test results for between-experiment comparisons

		N	Mean	SD	SE	95% CI for mean	*df*	*t*	*p*	Cohen's *d*
ART1	EXP1	20	104.40	12.91	2.89	(98.36, 110.44)	33.2	2.52	.017	0.81
	EXP2	20	91.30	19.29	4.31	(82.27, 100.33)				
ART2	EXP1	20	95.15	16.94	3.79	(87.22, 103.08)	37.8	0.76	.449	0.24
	EXP2	20	91.20	15.73	3.52	(83.84, 98.56)				
ART3	EXP1	20	106.95	17.79	3.98	(98.63, 115.27)	34.8	2.71	.010	0.87
	EXP2	20	93.60	13.03	2.91	(87.50, 99.70)				

Independent samples t-tests were used to compare overall usability and trust scores between experiments (see Fig. 54). Usability and Trust Survey scores were higher in EXP1 than in EXP2 across all ART levels, although this difference was not significant in ART2.

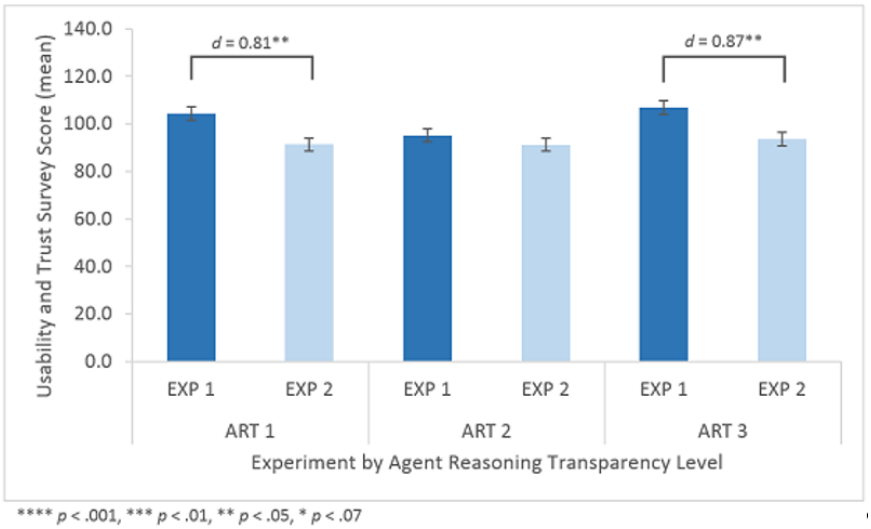

Fig. 54 Average Usability and Trust Survey score by experiment for each ART level; bars denote SE

Usability survey results were compared between experiments. Descriptive statistics for usability-survey scores and EXP1–EXP2 t-test results are shown in Table 37.

Table 37 Descriptive statistics for usability-survey score sorted by experiment for each ART level, and t-test results for between-experiment comparisons

		N	Mean	SD	SE	95% CI for mean	*df*	*t*	*p*	Cohen's *d*
ART1	EXP1	20	46.75	5.33	1.19	(44.26, 49.24)	35.1	3.20	.003	1.02
	EXP2	20	40.35	7.18	1.61	(36.99, 43.71)				
ART2	EXP1	20	40.75	6.60	1.48	(37.66, 43.84)	37.7	0.65	.520	0.21
	EXP2	20	39.45	6.05	1.35	(36.62, 42.28)				
ART3	EXP1	20	46.20	5.90	1.32	(43.44, 48.96)	38.0	2.51	.017	0.79
	EXP2	20	41.60	5.70	1.27	(38.93, 44.27)				

Examining the usability scores separately from the trust-survey scores, there is a significant difference in perceived usability between the 2 experiments. Usability scores were higher for EXP1 than EXP2 in ARTs 1 and 3 (see Fig. 55). This indicates the extra information provided in EXP2 affected the operator perception of agent usability in these ARTs. However, this appears to have been mitigated in ART2, where there was no significant difference in evaluation between the 2 experiments.

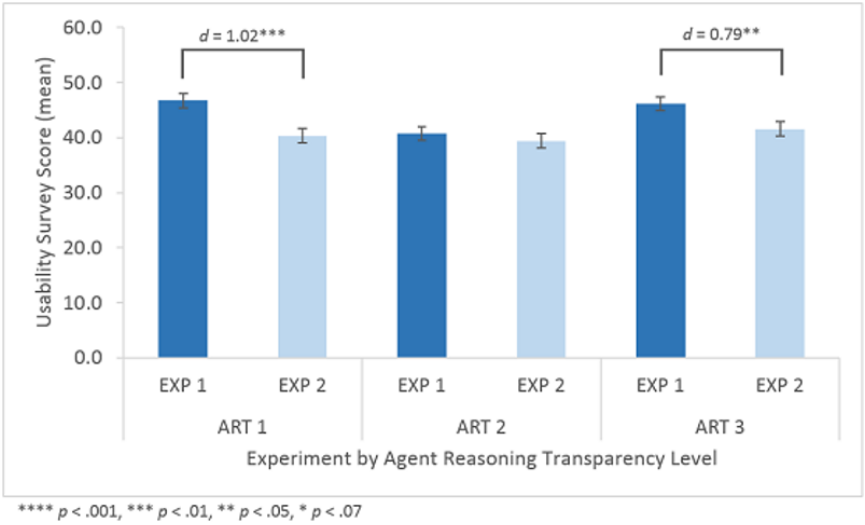

Fig. 55 Average usability-survey scores by experiment for each ART level; bars denote SE

Trust-survey results were compared between experiments. Descriptive statistics for rust-survey scores and EXP1–EXP2 t-test results are shown in Table 38.

Table 38 Descriptive statistics for trust-survey score sorted by experiment for each ART level, and t-test results for between-experiment comparisons

		N	Mean	SD	SE	95% CI for mean	*Df*	*t*	*p*	Cohen's *d*
ART1	EXP1	20	58.55	8.28	1.85	(54.67, 62.43)	32.1	2.20	.035	0.71
	EXP2	20	50.95	13.08	2.92	(44.83, 57.07)				
ART2	EXP1	20	54.40	10.23	2.29	(49.61, 59.19)	37.7	0.78	.439	0.25
	EXP2	20	51.75	11.19	2.50	(46.51, 56.99)				
ART3	EXP1	20	61.60	11.72	2.62	(56.12, 67.08)	34.9	2.95	.006	0.94
	EXP2	20	52.00	8.61	1.93	(47.97, 56.03)				

Examining the trust scores separately from the usability-survey scores shows there is a significant difference in operator subjective trust between the 2 experiments. Trust scores were higher for EXP1 than EXP2 in all ART levels (see Fig. 56) and this difference was significant in ARTs 1 and 3. This indicates the extra information provided in EXP2 reduced operator trust in the agent. However, the access to agent reasoning in ART2 also reduced operator trust in EXP1, where there was no significant difference in trust-survey scores between the 2 experiments.

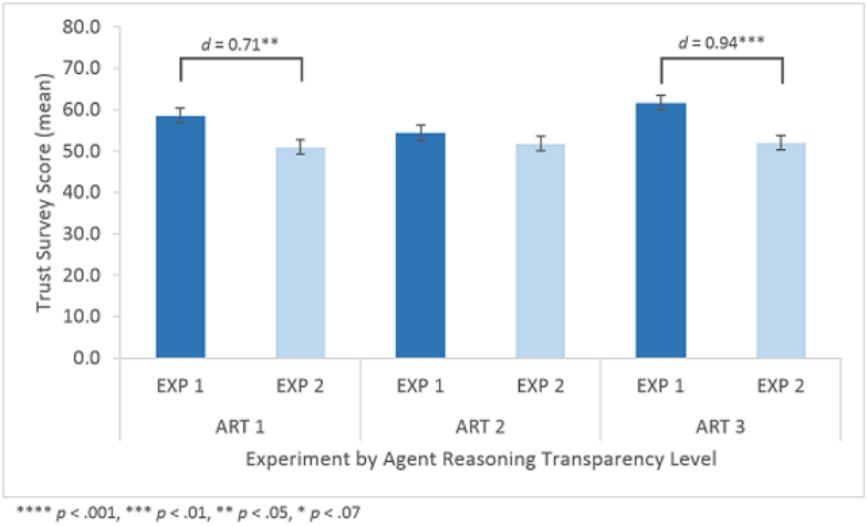

Fig. 56 Average trust-survey scores by experiment for each ART level; bars denote SE

5.3.4 Workload Evaluation

Hypothesis 4: Operator perceived workload will be greater in EXP2 than in EXP1 for all ARTs (EXP1 < EXP2). Objective measures of workload (i.e., PDia, FC, and FD) will also show increased workload.

Operator perceived workload was evaluated using the NASA-TLX workload survey and results were compared between experiments. Descriptive statistics for global NASA-TLX scores and EXP1–EXP2 t-test results are shown in Table 39.

Table 39 Descriptive statistics for global NASA-TLX scores sorted by experiment for each ART level, and t-test results for between-experiment comparisons

	N	Mean	SD	SE	95% CI for mean	*df*	*t*	*p*	Cohen's *d*
EXP1	20	64.70	13.47	3.01	(58.40, 70.01)	36.4	–0.60	.550	0.19
EXP2	20	67.03	10.87	2.43	(61.95, 72.12)				
EXP1	20	65.19	12.38	2.77	(59.39, 70.98)	37.6	0.58	.569	0.18
EXP2	20	62.80	13.89	3.08	(56.35, 69.25)				
EXP1	20	60.70	14.01	3.13	(54.15, 67.26)	36.7	–0.19	.848	0.06
EXP2	20	61.48	11.58	2.59	(56.06, 66.90)				

Using independent samples t-tests to compare findings, no significant difference in global NASA-TLX scores was found between experiments (see Fig. 57).

Fig. 57 Average global NASA-TLX score by experiment for each ART level; bars denote SE

Cognitive workload was also evaluated using several ocular indices and results were compared between experiments. Descriptive statistics for PDia, FC, and FD and EXP1–EXP2 t-test results are shown in Tables 40, 41, and 42, respectively.

Table 40 Descriptive statistics for PDia sorted by experiment for each ART level, and t-test results for between-experiment comparisons

		N	Mean	SD	SE	95% CI for mean	*Df*	*t*	*p*	Cohen's *d*
ART1	EXP1	19	3.74	0.31	0.07	(3.58, 3.94)	25.7	–0.20	.844	0.07
	EXP2	18	3.77	0.58	0.14	(3.48, 4.06)				
ART2	EXP1	20	3.62	0.35	0.08	(3.46, 3.78)	34.8	1.79	.082	0.59
	EXP2	17	3.43	0.32	0.08	(3.26, 3.59)				
ART3	EXP1	19	3.51	0.40	0.09	(3.31, 3.70)	34.0	0.23	.820	0.08
	EXP2	17	3.48	0.36	0.09	(3.29, 3.66)				

Table 41 Descriptive statistics for FC sorted by experiment for each ART level, and t-test results for between-experiment comparisons

		N	Mean	SD	SE	95% CI for mean	*df*	*t*	*p*	Cohen's *d*
ART1	EXP1	19	4830.81	689.30	158.14	(4498.58, 5163.04)	34.9	–0.16	.877	0.05
	EXP2	18	4864.48	620.01	146.14	(4556.16, 5172.80)				
ART2	EXP1	20	5109.85	819.94	183.34	(4726.10, 5493.59)	35.0	0.64	.526	0.21
	EXP2	17	4949.58	701.14	170.05	(4589.09, 5310.07)				
ART3	EXP1	19	4897.41	667.18	153.06	(4575.84, 5218.98)	33.4	–0.43	.667	0.15
	EXP2	17	4995.22	680.51	165.05	(4645.33, 5345.10)				

Table 42 Descriptive statistics for FD sorted by experiment for each ART level, and t-test results for between-experiment comparisons

		N	Mean	SD	SE	95% CI for mean	*df*	*t*	*p*	Cohen's *d*
ART1	EXP1	19	260.82	40.24	9.23	(241.43, 280.22)	35.0	–1.42	.165	0.47
	EXP2	18	279.20	38.57	9.09	(260.01, 298.38)				
ART2	EXP1	20	276.59	37.11	8.30	(259.23, 293.96)	31.7	0.95	.351	0.32
	EXP2	17	263.89	43.44	10.54	(241.55, 286.22)				
ART3	EXP1	19	267.18	38.98	8.94	(248.39, 285.97)	33.9	–0.38	.709	0.13
	EXP2	17	271.67	32.62	7.91	(254.90, 288.44)				

Using independent samples t-tests to compare findings, no significant difference in workload between experiments was found for any agent reasoning transparency level, as evaluated using eye-measure metrics.

5.3.5 SA Evaluation

Hypothesis 5: The increased environmental information will result in lower SA scores in EXP2 than in EXP1 in ARTs 1 and 3 (EXP1 > EXP2) for SA1 and SA3 measures. SA2 scores will be higher in EXP2 than in EXP1 in ARTs 1 and 2; however, SA2 scores will be lower in ART3:

SA1: ARTs 1, 2, and 3: EXP1 > EXP2.

SA2: ARTs 1 and 2: EXP1 < EXP2; ART3: EXP1 > EXP2.

SA3: ARTs 1, 2, and 3: EXP1 > EXP2.

Descriptive statistics for SA1 scores and EXP1–EXP2 t-test results are shown in Table 43.

Table 43 Descriptive statistics for SA1 scores sorted by experiment for each ART level, and t-test results for between-experiment comparisons

		N	Mean	SD	SE	95% CI for mean	*df*	*t*	*p*	Cohen's *d*
ART1	EXP1	20	1.35	4.93	1.10	(–0.96, 3.66)	37.3	–0.17	.865	0.05
	EXP2	20	1.60	4.31	0.96	(–0.42, 3.62)				
ART2	EXP1	20	0.10	5.86	1.31	(–2.64, 2.84)	32.8	–1.37	.179	0.44
	EXP2	20	2.25	3.84	0.86	(0.45, 4.05)				
ART3	EXP1	20	3.85	3.65	0.82	(2.14, 5.56)	33.2	1.57	.125	0.51
	EXP2	20	1.55	5.43	1.22	(–0.99, 4.09)				

SA1 scores were expected to be lower in EXP2 than in EXP1 in all ART levels. When comparing results from EXP1 to EXP2 it is evident SA1 scores varied widely between experiments and ART levels; however, there were no significant differences between EXP2 and EXP1 at any ART level. The hypothesis was not supported.

Descriptive statistics for SA2 scores and EXP1–EXP2 t-test results are shown in Table 44.

Table 44 Descriptive statistics for SA2 scores sorted by experiment for each ART level, and t-test results for between-experiment comparisons

		N	Mean	SD	SE	95% CI for mean	*df*	*t*	*p*	Cohen's *d*
ART1	EXP1	20	10.90	4.51	1.01	(8.79, 13.01)	35.1	–3.11	.004	0.99
	EXP2	20	14.80	3.35	0.75	(13.23, 16.37)				
ART2	EXP1	20	12.55	3.76	0.84	(10.79, 14.31)	28.8	–0.36	.722	0.12
	EXP2	20	13.20	7.15	1.60	(9.85, 16.55)				
ART3	EXP1	20	11.25	4.96	1.11	(8.93, 13.57)	36.1	–2.21	.034	0.70
	EXP2	20	15.20	6.28	1.40	(12.26, 18.14)				

SA2 scores were expected to be lower in EXP1 than in EXP2 in ART Levels 1 and 2, but higher in EXP1 than EXP2 in ART3. Comparing results from EXP1 to EXP2, it is evident that SA2 scores were higher in EXP2 than in EXP1 for all ART levels although this difference was not significant in ART2 (see Fig. 58). Thus, the hypothesis was partially supported. The additional environmental information in EXP2 did improve SA2 scores in ART1, compared to EXP1, which supported the hypothesis. In ART3, the high-information environment and the increased access to agent transparency were expected to overload the operator, resulting in lower SA2 scores in EXP2 than in EXP1. However, this was not the case. Participants in EXP2 had higher SA2 scores than their EXP1 counterparts, contrary to the stated hypothesis.

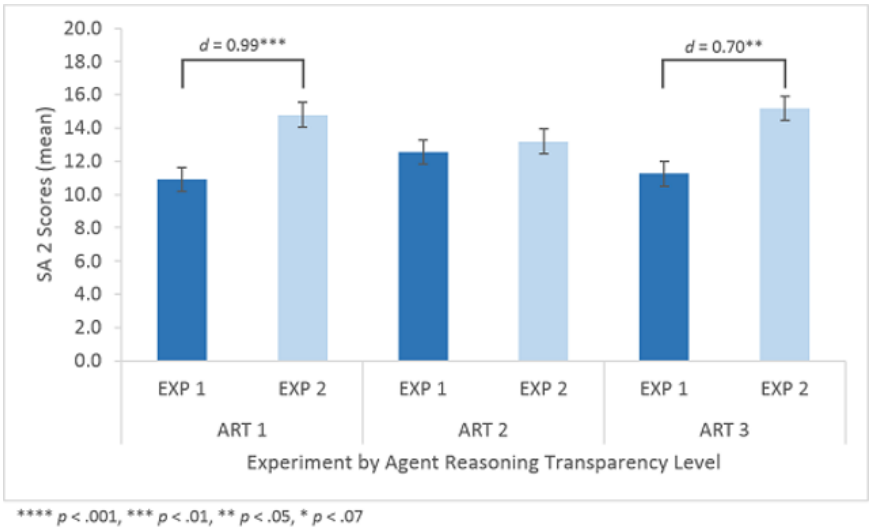

Fig. 58 Average SA2 scores by experiment for each (ART) level; bars denote SE

SA3 scores were compared between experiments. Descriptive statistics for SA3 scores and EXP1–EXP2 t-test results are shown in Table 45.

Table 45 Descriptive statistics for SA3 scores sorted by experiment for each ART level, and t-test results for between-experiment comparisons

		N	Mean	SD	SE	95% CI for mean	*df*	*t*	*p*	Cohen's *d*
ART1	EXP1	20	1.90	10.22	2.29	(–2.88, 6.68)	37.7	–0.32	.749	0.10
	EXP2	20	2.90	9.40	2.10	(–1.50, 7.30)				
ART2	EXP1	20	3.35	10.43	2.33	(–1.53, 8.23)	36.5	–0.96	.342	0.31
	EXP2	20	0.45	8.51	1.90	(–3.53, 4.43)				
ART3	EXP1	20	8.10	7.18	1.61	(4.74, 11.46)	36.6	2.41	.021	0.76
	EXP2	20	2.00	8.78	1.96	(–2.11, 6.11)				

SA3 scores were expected to be lower in EXP2 than in EXP1 in all ART levels. Comparing results from EXP1 to EXP2 showed SA3 scores were significantly higher in EXP1 than in EXP2 for ART3, but not significantly different in ARTs 1 and 2 (see Fig. 59). Thus, the hypothesis was partially supported. In ART3, the high-information environment and the increased access to agent transparency were expected to overload the operator, resulting in lower SA3 scores in EXP2 than in EXP1.

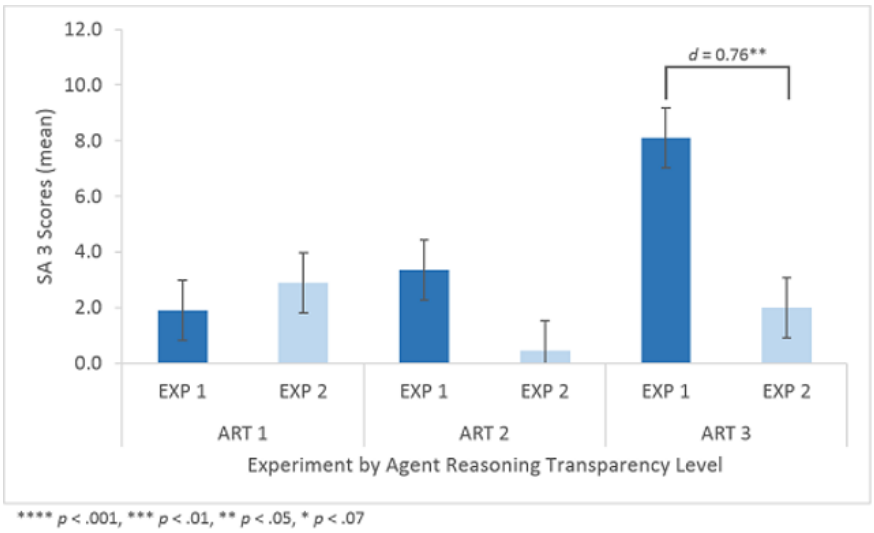

Fig. 59 Average SA3 score by experiment for each ART level; bars denote SE

5.3.6 Target-Detection Task Performance

Hypothesis 6: Performance in the target-detection task, in both targets detected and false alarms, will be worse in EXP2 than in EXP1 in all ARTs due to information overload:

- Number of targets detected: EXP1 > EXP2.
- FAs: EXP1 < EXP2.

Descriptive statistics for target-detection task scores and EXP1–EXP2 t-test results are shown in Table 46.

Table 46 Descriptive statistics for target-detection scores sorted by experiment for each ART level, and t-test results for between-experiment comparisons

		N	Mean	SD	SE	95% CI for mean	*df*	*t*	*p*	Cohen's *d*
ART1	EXP1	20	44.45	10.10	2.26	(39.72, 49.18)	37.8	–0.24	.812	0.08
	EXP2	20	45.25	10.96	2.45	(40.12, 50.38)				
ART2	EXP1	20	45.05	13.64	3.05	(38.66, 51.44)	36.0	–0.67	.507	0.21
	EXP2	20	47.65	10.74	2.40	(42.62, 52.68)				
ART3	EXP1	20	44.75	10.19	2.28	(39.98, 49.52)	35.6	1.19	.242	0.38
	EXP2	20	40.30	13.28	2.97	(34.09, 46.51)				

Target-detection task scores were expected to be lower in EXP2 than in EXP1 in all ART levels. Comparing results from EXP1 to EXP2 shows target-detection scores were not significantly different in any ART level. Thus, the hypothesis was not supported.

Descriptive statistics for the number of reported FAs and EXP1–EXP2 t-test results are shown in Table 47.

Table 47 Descriptive statistics for FAs (count) sorted by experiment for each ART level, and t-test results for between-experiment comparisons

		N	Mean	SD	SE	95% CI for mean	*df*	*t*	*p*	Cohen's *d*
ART1	EXP1	20	20.80	6.25	1.40	(17.87, 23.73)	38.0	2.29	.028	0.72
	EXP2	20	16.30	6.18	1.38	(13.41, 19.19)				
ART2	EXP1	20	16.35	5.29	1.18	(13.87, 18.83)	37.8	–0.19	.854	0.06
	EXP2	20	16.65	4.97	1.11	(14.33, 18.97)				
ART3	EXP1	20	15.25	3.89	0.87	(13.43, 17.07)	32.2	–0.40	.691	0.13
	EXP2	20	15.90	6.12	1.37	(13.04, 18.76)				

Reported FAs were expected to be lower in EXP1 than in EXP2 in all ART levels. When comparing results from EXP1 to EXP2, there are significantly more FAs reported in EXP1 than in EXP2 in ART1 but no significant difference in ARTs 2 and 3 (see Fig. 60). Thus, the hypothesis was partially supported.

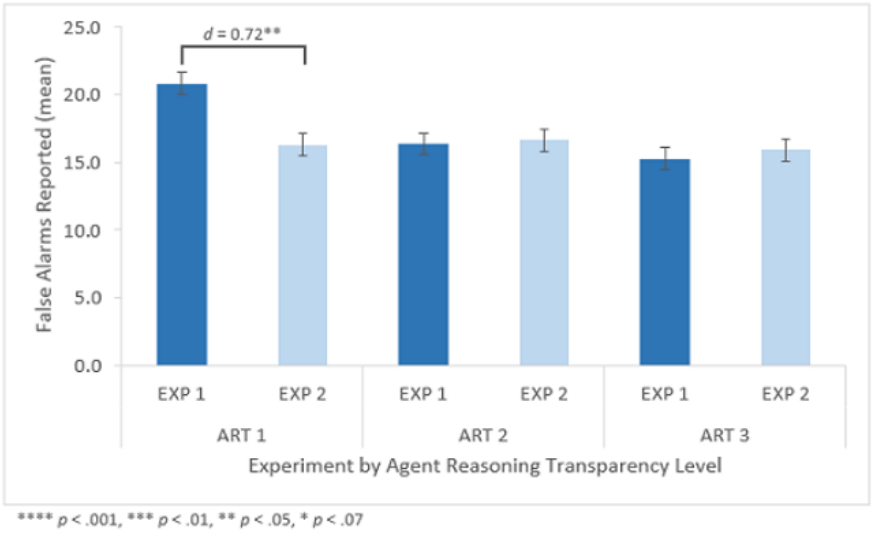

Fig. 60 Average reported FAs by experiment for each ART level; bars denote SE

In each experiment, results of the target-detection task were also evaluated using SDT to determine if there were differences in sensitivity (*d'*) or selection bias (Beta) among the 3 ARTs. These comparisons follow. Descriptive statistics and EXP1–EXP2 t-test results for sensitivity (*d'*) are shown in Table 48.

Table 48 Descriptive statistics for d' scores, sorted by experiment (EXP), for each agent reasoning transparency (ART) level, and t-test results for between-experiment comparisons

		N	Mean	SD	SE	95% CI for mean	*df*	*t*	*p*	Cohen's *d*
ART1	EXP1	20	2.20	0.32	0.07	(2.05, 2.35)	36.4	–0.85	.400	0.27
	EXP2	20	2.30	0.40	0.09	(2.11, 2.49)				
ART2	EXP1	20	2.31	0.43	0.10	(2.11, 2.52)	36.6	–0.49	.626	0.16
	EXP2	20	2.38	0.35	0.08	(2.21, 2.54)				
ART3	EXP1	20	2.29	0.38	0.09	(2.11, 2.46)	37.3	0.73	.467	0.23
	EXP2	20	2.19	0.44	0.10	(1.99, 2.39)				

Target-detection task scores were expected to be lower in EXP2 than in EXP1 in all ART levels, so it would be expected that sensitivity to target presence would be higher in EXP1 compared to EXP2. Comparing results from EXP1 to EXP2 showed mean *d'* scores for EXP2 were higher than those in EXP1 in ARTs 1 and 2, which was contrary to the expected results. However, these results were not significant. The mean *d'* scores in ART3 were higher in EXP1 than in EXP2, which was in the expected direction. However, this finding was not significant. Thus, the hypothesis was not supported.

Descriptive statistics and EXP1–EXP2 t-test results for selection bias (Beta) are shown in Table 49.

Table 49 Descriptive statistics for Beta scores sorted by experiment for each ART level, and t-test results for between-experiment comparisons

		N	Mean	SD	SE	95% CI for mean	*df*	*t*	*p*	Cohen's *d*
ART1	EXP1	20	2.42	0.28	0.06	(2.29, 2.56)	36.8	–2.22	.033	0.70
	EXP2	20	2.64	0.34	0.08	(2.48, 2.80)				
ART2	EXP1	20	2.59	0.35	0.08	(2.43, 2.76)	34.0	–0.11	.912	0.04
	EXP2	20	2.60	0.25	0.06	(2.49, 2.72)				
ART3	EXP1	20	2.60	0.37	0.08	(2.43, 2.78)	37.9	–0.39	.701	0.12
	EXP2	20	2.65	0.39	0.09	(2.47, 2.83)				

The number of reported FAs were expected to be lower in EXP1 than in EXP2 in all ART levels, so it would be expected that selection bias (Beta) would be stricter (higher Beta scores) in EXP1 compared to EXP2. Comparing results from EXP1 to EXP2 makes evident that mean Beta scores for EXP2 were significantly higher than those in EXP1 in ART1. However, there was no significant difference in Beta scores between the 2 experiments in ARTs 2 and 3 (see Fig. 61). The lower Beta scores for EXP1 for ART1 indicate a looser selection criterion was used in this setting, agreeing with the finding that there were more reported FAs in this condition. This is evidence the additional environmental information supplied in EXP2 supported this task, most likely by removing ambiguity for the operator, thus

freeing their attention from the route-selection task so that it could be directed to the target-detection task. However, the hypothesis was not supported.

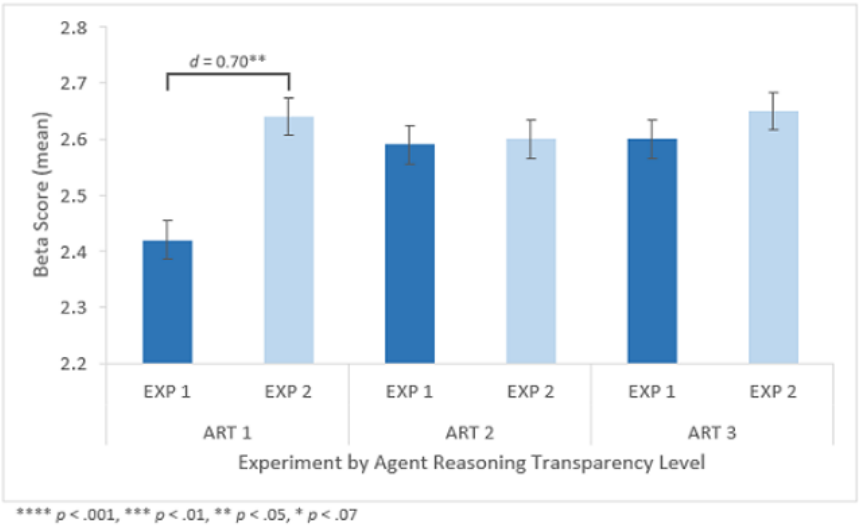

Fig. 61 Average Beta scores by experiment for each ART level; bars denote SE

5.4 Discussion

The primary goal of this study was to examine how differing levels of information regarding the task environment and ART affected complacent behavior in a route-selection task. In 2 experiments, participants supervised a 3-vehicle convoy as it traversed a simulated environment and rerouted the convoy when needed with the assistance of an intelligent agent, RoboLeader. Participants received communications from a commander confirming either the presence or absence of activity in the area. They also received information regarding potential events along their route via icons that appeared on a map displaying the convoy route and surrounding area. Participants in EXP1 (low-information setting) received information about their current route only; they did not receive any information about the suggested alternate route. However, they were instructed that the proposed path was at least as safe as their original route. Participants in EXP2 (high-information setting) received information about both their current route and the agent-recommended alternative route. When the convoy approached a potentially unsafe area, the intelligent agent would recommend rerouting the convoy. The agent recommendations were correct 66% of the time. The participant was required to recognize and correctly reject any incorrect suggestions. The secondary goal of this study was to examine how differing levels of information affected main-task and secondary-task performance, response time, workload, SA, trust, and system usability.

Complacent behavior was quantified as incorrect acceptances of agent suggestion (Parasuraman et al. 2000) and evaluated via primary (route-selection) task response at those decision points where the agent recommendation was incorrect. Increased environmental information was predicted to reduce the number of incorrect acceptances except when the agent reasoning included information that may be ambiguous for the operator. This prediction was partially supported, as the number of incorrect acceptances was lower in all ARTs in EXP2 than in EXP1. However, the participants in the high-information setting (in all ART conditions) may have been more inclined to reject the agent suggestion overall, as the information manipulation gave them more reasons to reject than accept (Shafir 1993). As such, the low number of incorrect acceptances in EXP2 is not particularly informative on its own.

In ART2, participants in EXP1 reduced their incorrect acceptances to nearly the same as those in EXP2. Considering that the number of incorrect acceptances for EXP2 were the same in all ARTs, this result underscores how effective the addition of ART was in EXP1 in mitigating complacent behavior. There were also interesting differences in the amount of time it took participants to reach their decisions. Even though there was more information available in EXP2 than in EXP1, participants in EXP2 did not take any more time to respond (whether correctly or incorrectly) to the agent suggestion in ART1 than those in EXP1, which may suggest that the additional route information also encouraged more complacent behavior in the absence of agent reasoning. Decision times were significantly longer in ART2 in EXP2 than those in EXP1, particularly for incorrect acceptances, which were nearly twice as long as their DTs for correct rejections. This could indicate difficulty integrating the information or, more likely, difficulty deciding to accept (albeit incorrectly) the agent suggestion in the face of the additional inducement to reject.

Participants in ART3 in EXP2 also had significantly longer DTs for correct rejections than their EXP1 counterparts. However there was no significant difference in their DTs for incorrect acceptances. Considering the results from the other ARTs, it is reasonable to deduce this lack of difference in DTs could indicate an overwork situation that encouraged more complacent behavior.

Overall performance on the route-selection task was predicted to be worse in the high-information setting, except in ART2, when performance in the high-information setting would be improved. These predictions were not supported; there was no difference in route-selection scores in ARTs 1 or 3 between the 2 experiments and route-selection task scores were lower in ART2 for EXP2 than for EXP1. As previously discussed, these results are most likely due to the added inducement to reject that was present in EXP2. While DTs were longer in EXP2

than in EXP1 for route-selection choices, these findings were anticipated and did not indicate any supervisory-control issues.

Operator trust of the agent was expected to be greater in EXP2 than in EXP1, except when access to agent reasoning was at its highest (ART3). Incorrect rejections of the agent recommendation when the agent was correct, along with the associated DTs, were assessed as objective indicators of operator trust. There were significantly more incorrect rejections in EXP2 than in EXP1 in all ARTs. The increased number of incorrect rejections in EXP2 is most likely due to the increase in task-environment information, which probably encouraged participants to reject the agent suggestion. Participants took longer deliberating in EXP2 than EXP1 in all ARTs. The difference in DTs between experiments for ART1 was not significant, which could indicate the increase in information alone did not result in any associated increase in DT. In ART2 the DTs were significantly longer in EXP2 than in EXP1, and this difference was twice as long for incorrect rejections as for correct acceptances. Considering this, it is most likely this increase is an indication of difficulty integrating the available information rather than a reflection of the operators trust in the agent. In ART3, the difference in DTs between experiments was significant for correct acceptances. However, there was no significant difference in DTs for incorrect rejections even though there were considerably more incorrect rejections in EXP2 than in EXP1. This could indicate the incorrect rejections in ART3 were due to an overwork situation rather than difficulty integrating information (i.e., complacent behavior or overtrust). Taken as a whole, the objective assessments of operator trust indicate no discernable distrust of the agent. However, there could be indications of overtrust when ART was at its highest.

The Usability and Trust Survey, the subjective measure of operator trust, indicates that in 2 conditions, ART1—when no agent reasoning was available—and ART3—when ART was greatest—operators reported higher trust and greater usability in EXP1 than in EXP2. However, in ART2—when ART was available but contained no information that would be considered ambiguous or subjective—there was no difference in operator trust of reported usability. Therefore, the hypothesis was only partially supported. In the high-information setting, operators appeared to question the agent suggestions more and reported lower trust and usability than in the low-information setting. These findings agree with previous research that found when operators question the agent's accuracy and rationale they will demonstrate reduced trust and reliance on the agent (Linegang et al. 2006; Lyons and Havig 2014). Operator workload was expected to be greater in the high-information setting than in the low-information setting. However, this hypothesis was not supported. Workload was evaluated using the NASA-TLX and several ocular indices that have

been shown to be informative as to cognitive workload. Similar to findings by Mercado et al. (2015), there were no significant differences in global NASA-TLX scores or eye-behavior metrics due to information level.

Situation-awareness scores were hypothesized to be lower in the high-information setting than the low-information setting, with the exception of SA2 scores in ART2. There was no difference in SA1 scores between experiments. Contrary to the predicted outcome, SA2 scores were higher in the high-information setting when ART was not available and again when ART was at its highest. However, there was no difference in SA2 scores between experiments in ART2. There was no difference in SA3 scores between the 2 experiments except in the highest ART condition, where scores in the low-information setting were much higher than those in the high-information setting. These findings partially support the hypothesis. Operator comprehension (SA2) benefitted from the increased level of information in EXP2 when ART was not available and again when it was ambiguous.

Performance on the secondary task, target detection, was not different between the 2 experiments. However, the number of FAs was greater in the low-information setting than in the high-information setting when ART was not available. Higher Beta scores indicate participants were using a looser selection criterion in ART1 in the low-information setting than in the high, indicating that having more information about their task environment allowed them to be more discerning when conducting the target-detection task.

There were several limitations to this comparative analysis. First, the ART in EXP2 was arguably greater than that in EXP1, as it contained the weight factors that were not present in EXP1. Therefore, within-condition comparisons contained analysis that attempted to tease apart the effects from the increase in ART from those that resulted from the increase in environmental information. A second limitation would be the study paradigm itself. At each decision point, the participant is not choosing which path to take so much as they are deciding whether to reject the agent suggestion. In EXP1, where there is no other information available about the agent's recommended route, there is no strong reason to reject the route. However, in EXP2, where the participants receive information about the alternative route, they receive 2 pieces of information as compared to the one piece of information they have about their original route. According to decision theory, this additional information would make it more likely the participant would reject the agent suggestion (Shafir 1993). Thus, the comparison of the effect of information level between the 2 experiments is not equitable. A third limitation is a difference in information between EXP1 and EXP2. In EXP1, the participant is given one piece of information about their main path and no information about the alternative route. In EXP2 the participant is given one piece of information about the main path and

2 pieces of information about the alternative route. Hence, the comparison is not of the effects of an increase in information as much as it is of the difference between no information and some information. While these limitations do not negate the findings of the comparative analysis, their potential effect on the outcome of this comparison warrants caution in the interpretation of the comparison and generalizing the findings to larger populations.

5.5 Conclusion

Understanding the interaction between the amount of information available to the operator and the transparency of agent reasoning is important to designers of intelligent recommender and decision-aid systems. To that end, we examined how the amount of task-environment information the operator had and the increase in ART affected complacent behavior as well as task performance, workload, and trust.

The amount of information the operator had regarding the task environment had a profound effect on their proper use of the agent. Increased environmental information resulted in more rejections of the agent recommendation regardless of the transparency of agent reasoning. The way in which the information was presented in EXP2 appeared to create a situation wherein operators were encouraged to reject the agent recommendation. Even so, the addition of ART appeared to be effective at countering this bias by keeping the operator engaged.

Objective evidence indicated probable complacent behavior in the high-information setting when agent reasoning was either not transparent or so transparent as to become ambiguous. However, operators reported lower trust and usability for the agent than when environmental information was limited. This suggests dissonance between operator performance and operator perception of the agent.

Situation-awareness (SA2) scores were also higher in the high-information environment when agent reasoning was either not transparent or so transparent as to become ambiguous, compared to the low-information environment. However, when a moderate amount of agent reasoning was available to the operator, the amount of information available had no effect on the operator's complacent behavior, subjective trust, or SA. These findings indicate some negative outcomes from the incongruous transparency of agent reasoning may be mitigated by increasing the task-environment information the operator has.

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Appendix A. Demographics Questionnaire

This appendix appears in its original form, without editorial change.

Demographic Questionnaire

Date: _____ Participant ID: _____

1. General Information

a. Age: _____ Gender: M F Handedness: L R

b. How long ago did you have an eye exam? Within the last (Circle one):
6 months 1 year 2 years 4 years or more

c. Do you have any of the following (Circle all that apply):
Astigmatism Near-sightedness Far-sightedness Other (explain): _____

d. Do you have corrected vision (Circle one)? Yes No Glasses Contact Lenses
If so, are you wearing them today? Yes No

e. Are you in your good/ comfortable state of health physically? YES NO
If NO, please briefly explain:

f. How many hours of sleep did you get last night? _____ hours

2. Military Experience

a. Do you have prior military service? YES NO If Yes, how long _____

3. Educational Data

a. What is your highest level of education completed? Select one.

____ GED ____ Bachelor's Degree

____ High School ____ M.S/M.A

____ Some College ____ Ph.D.

____ Associates or Technical Degree

What subject is your degree in (for example, Engineering)? _____

4. Computer Experience

a. How long have you been using a computer?
__Less than 1 year ___1-3 years ___4-6 years ___7-10 years ___10 years or more

b. How often do you play computer/video games? (Circle one)
Daily 3-4X/ Week Weekly Monthly Once or twice a year Never

c. Enter the names of the games you play most frequently:
_____

d. How often do you operate a radio-controlled vehicle (car, boat, or plane)?
Daily Weekly Monthly Once or twice a year Never

e. How often do you use graphics/drawing features in software packages?
Daily Weekly Monthly Once or twice a year Never

Appendix B. Attentional Control Survey

This appendix appears in its original form, without editorial change.

Attentional Control Survey **Participant #_____** **Date _____**

For each of the following questions, circle the response that best describes you.

It is very hard for me to concentrate on a difficult task when there are noises around.
Almost never, Sometimes, Often, Always

When I need to concentrate and solve a problem, I have trouble focusing my attention.
Almost never, Sometimes, Often, Always

When I am working hard on something, I still get distracted by events around me.
Almost never, Sometimes, Often, Always

My concentration is good even if there is music in the room around me.
Almost never, Sometimes, Often, Always

When concentrating, I can focus my attention so that I become unaware of what's going on in the room around me.
Almost never, Sometimes, Often, Always

When I am reading or studying, I am easily distracted if there are people talking in the same room.
Almost never, Sometimes, Often, Always

When trying to focus my attention on something, I have difficulty blocking out distracting thoughts.
Almost never, Sometimes, Often, Always

I have a hard time concentrating when I'm excited about something.
Almost never, Sometimes, Often, Always

When concentrating, I ignore feelings of hunger or thirst. Almost never, Sometimes, Often, Always

I can quickly switch from one task to another. Almost never, Sometimes, Often, Always

It takes me a while to get really involved in a new task. Almost never, Sometimes, Often, Always

It is difficult for me to coordinate my attention between the listening and writing required when taking notes during lectures. Almost never, Sometimes, Often, Always

I can become interested in a new topic very quickly when I need to.
Almost never, Sometimes, Often, Always

It is easy for me to read or write while I'm also talking on the phone.
Almost never, Sometimes, Often, Always

I have trouble carrying on two conversations at once. Almost never, Sometimes, Often, Always

I have a hard time coming up with new ideas quickly. Almost never, Sometimes, Often, Always

After being interrupted or distracted, I can easily shift my attention back to what I was doing before.
Almost never, Sometimes, Often, Always

When a distracting thought comes to mind, it is easy for me to shift my attention away from it.
Almost never, Sometimes, Often, Always

It is easy for me to alternate between two different tasks. Almost never, Sometimes, Often, Always

It is hard for me to break from one way of thinking about something and look at it from another point of view.
Almost never, Sometimes, Often, Always

Appendix C. Cube Comparisons Test

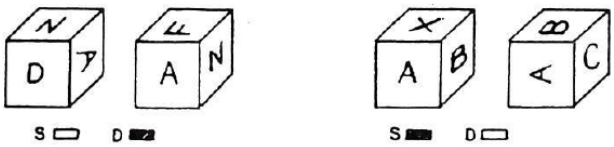
This appendix appears in its original form, without editorial change.

Cube Comparisons Test

Participant # _____ **Date _____**

CUBE COMPARISONS TEST -- S-2 (Rev.)

Wooden blocks such as children play with are often cubical with a different letter, number, or symbol on each of the six faces (top, bottom, four sides). Each problem in this test consists of drawings of pairs of cubes or blocks of this kind. Remember, there is a different design, number, or letter on each face of a given cube or block. Compare the two cubes in each pair below.

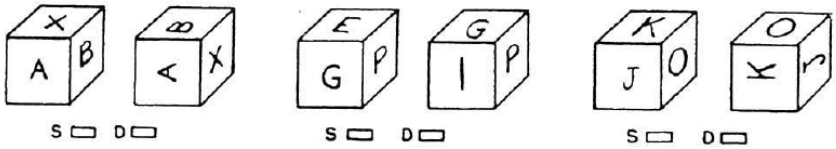


The first pair is marked D because they must be drawings of <u>different</u> cubes. If the left cube is turned so that the A is upright and facing you, the N would be to the left of the A and hidden, not to the right of the A as is shown on the right hand member of the pair. Thus, the drawings must be of different cubes.

The second pair is marked S because they could be drawings of the same cube. That is, if the A is turned on its side the X becomes hidden, the B is now on top, and the C (which was hidden) now appears. Thus the two drawings could be of the same cube.

<u>Note</u>: No letters, numbers, or symbols appear on more than one face of a given cube. Except for that, <u>any</u> letter, number or symbol can be on the hidden faces of a cube.

Work the three examples below.



The first pair immediately above should be marked D because the X cannot be at the peak of the A on the left hand drawing and at the base of the A on the right hand drawing. The second pair is "different" because P has its side next to G on the left hand cube but its top next to G on the right hand cube. The blocks in the third pair are the same, the J and K are just turned on their side, moving the O to the top.

Your score on this test will be the number marked correctly minus the number marked incorrectly. Therefore, it will <u>not</u> be to your advantage to guess unless you have some idea which choice is correct. Work as quickly as you can without sacrificing accuracy.

You will have <u>3 minutes</u> for each of the two parts of this test. Each part has one page. When you have finished Part 1, STOP.

DO NOT TURN THE PAGE UNTIL YOU ARE ASKED TO DO SO.

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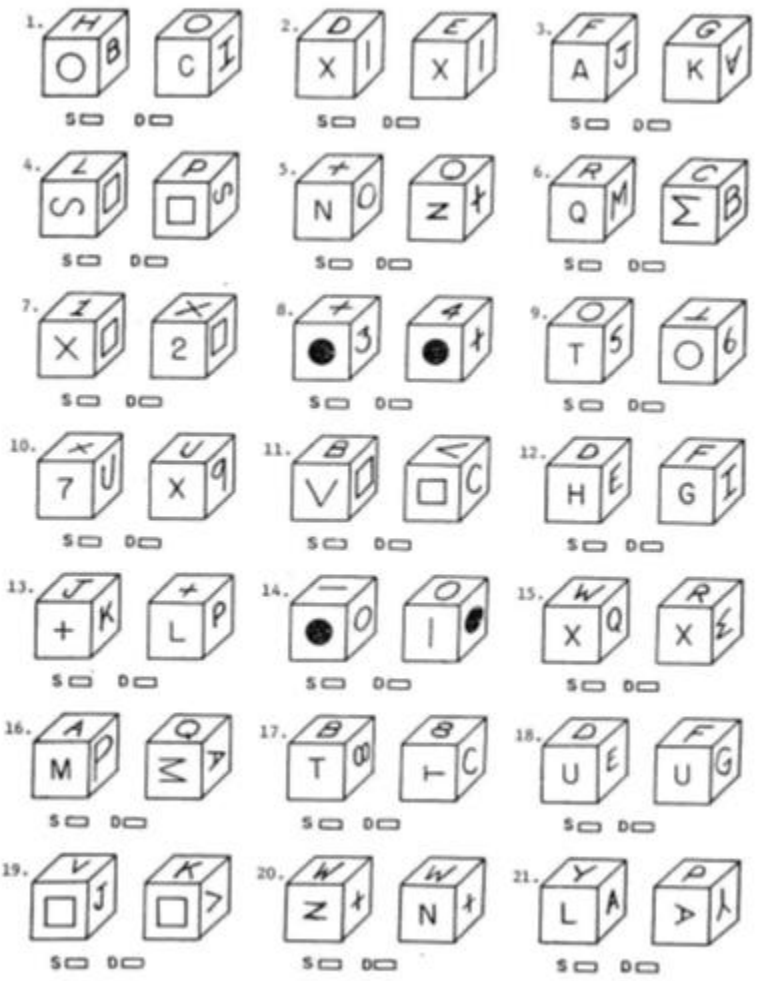
Part 1 (3 minutes)



DO NOT GO ON TO THE NEXT PAGE UNTIL ASKED TO DO SO. STOP.

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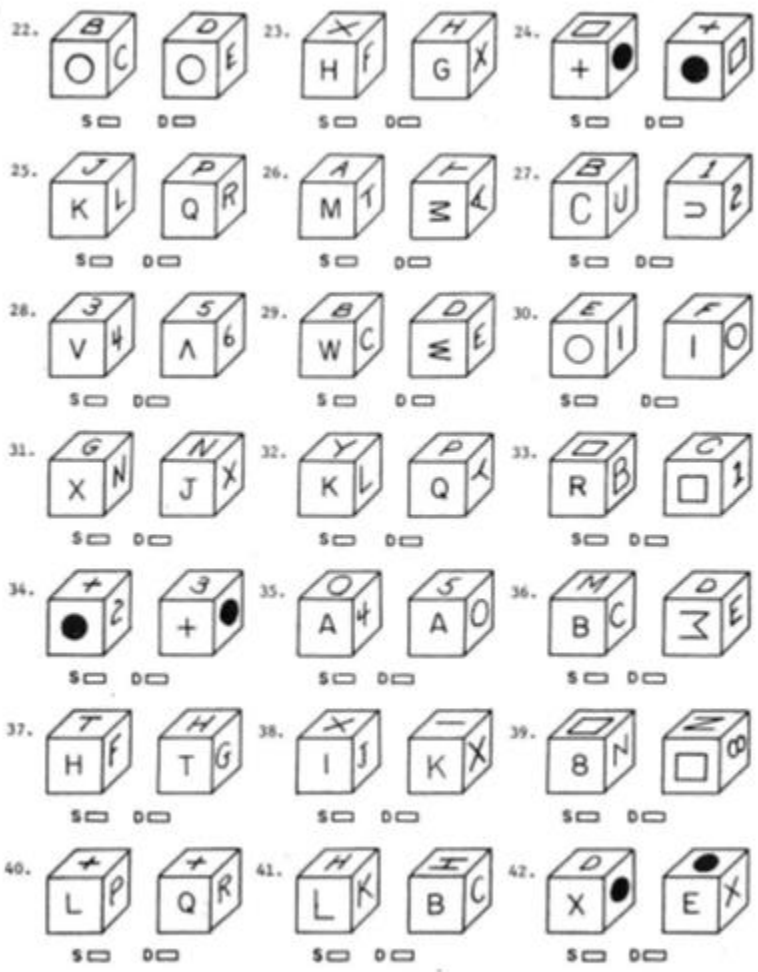
Part 2 (5 minutes)



DO NOT GO BACK TO PART 1 AND
DO NOT GO ON TO ANY OTHER TEST UNTIL ASKED TO DO SO. STOP.

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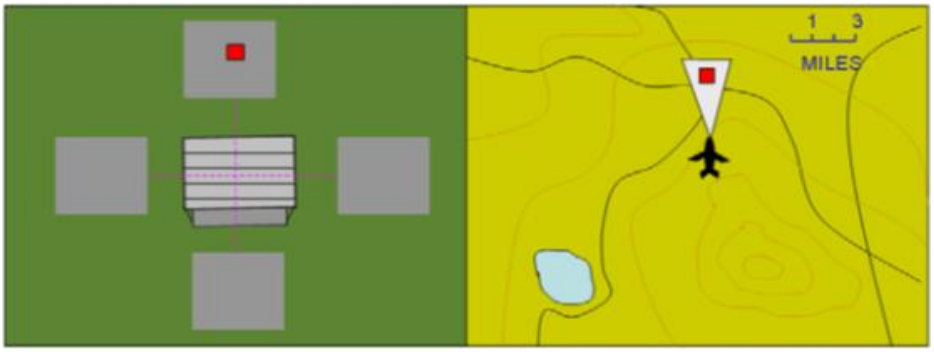
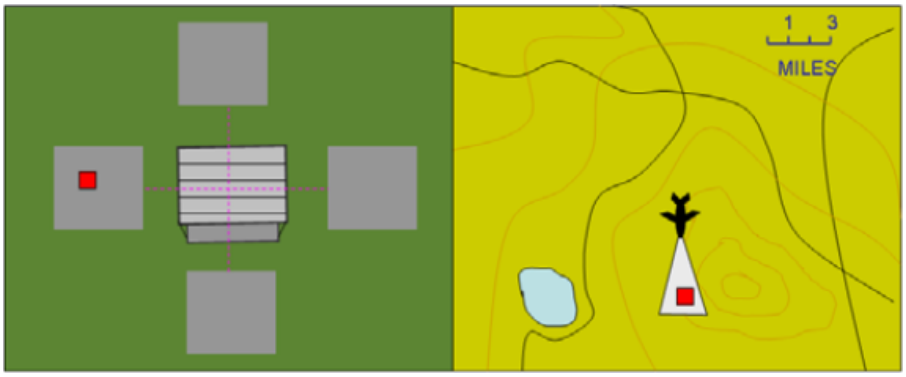
Appendix D. Spatial Orientation Test

The Spatial Orientation Test, modeled after the cardinal direction test developed by Gugerty and his colleagues,[1] is a computerized test consisting of a brief training segment and 32 test questions. The program automatically captures both accuracy and response time. Participants are shown the following image:



The right side image is of a map showing a plane flying. The left side of the display is the pilot's view (from the cockpit of the plane) of several parking lots surrounding a building. The participants' task is to use the right side of the display to learn which direction the plane is flying. They then use this information to identify which parking lot (north, south, east, or west) in the left-side image has the dot. In the example shown above, the plane is heading north and so the dot appears in the north parking lot. In the example shown below, the plane is heading south and so the dot appears in the east parking lot.



Participants are shown 32 of these images in succession; each time the direction the plane is flying and the location of the dot are randomized. Participants answer by clicking on one of 4 buttons (North, South, East, or West). This test is self-paced; the participant may take as long as they wish to answer, and when they answer one question the next question automatically appears. No questions can be skipped, and the order of images is randomized among participants.

[1]Gugerty L, Brooks J. Reference-frame misalignment and cardinal direction judgments: group differences and strategies. J Exp Psych: App. 2004;10(2):75–88.

Appendix E. National Aeronautics and Space Administration-Task Load Index (NASA-TLX)

This appendix appears in its original form, without editorial change.

NASA TLX Workload Assessment

Instructions: Ratings Scales

We are interested in the "workload" you experienced during this scenario. Workload is something experienced individually by each person. One way to find out about workload is to ask people to describe what they experienced. Workload may be caused by many different factors and we would like you to evaluate them individually. The set of six workload rating factors was developed for you to use in evaluating your experiences during different tasks. Please read them. If you have a question about any of the scales in the table, please ask about it. It is extremely important that they be clear to you.

Definitions

Title	Endpoints	Descriptions
MENTAL DEMAND	Low / High	How much mental and perceptual activity was required (that is, thinking, deciding, calculating, remembering, looking, searching, etc.)? Was the task easy or demanding, simple or complex, exacting or forgiving?
PHYSICAL DEMAND	Low / High	How much physical activity was required (that is, pushing, pulling, turning, controlling, activating, etc.)? Was the task easy or demanding, slow or brisk, slack or strenuous, restful or laborious?
TEMPORAL DEMAND	Low / High	How much time pressure did you feel due to the rate or pace at which the tasks or task elements occurred? Was the pace slow and leisurely or rapid and frantic?
PERFORMANCE	Poor / Good	How successful do you think you were in accomplishing the goals of the task? How satisfied were you with your performance in accomplishing these goals?
EFFORT	Low / High	How hard did you have to work (mentally and physically) to accomplish your level of performance?
FRUSTRATION LEVEL	Low / High	How insecure, discouraged, irritated, stressed, and annoyed versus secure, gratified, content, relaxed and complacent did you feel during the task?

We want you to evaluate workload. Rate the workload on each factor on a scale. Each scale has two end descriptions, and 20 slots (hash marks) between the end descriptions. Place an "x" in the slot (between the hash marks) that you feel most accurately reflects your workload.

After you have finished the entire series, we will be able to use the pattern of your choices to create a weighted combination of ratings into a summary workload score.

We ask you to evaluate your workload for this scenario. This includes all the duties involved in your job (e.g., detecting targets and using display).

Participant ID: _____

TLX Workload Scale

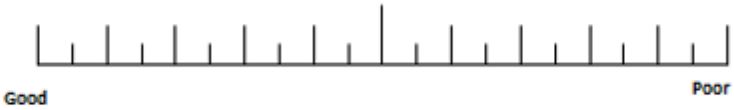
Please rate your workload by putting a mark on each of the six scales at the point which matches your experience.

Mental Demand

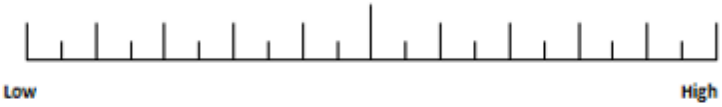
Physical Demand

Temporal Demand

Performance



Effort



Frustration

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Appendix F. Complacency Potential Rating Scale

This appendix appears in its original form, without editorial change.

Complacency Potential Rating Scale

Participant # _____ 2

Read each statement carefully and circle the one response that you feel most accurately describes your views and experiences. THERE ARE NO RIGHT OR WRONG ANSWERS. Please answer honestly and do not skip any questions.

SA	A	U	D	SD
Strongly agree	Agree	Undecided	Disagree	Strongly disagree

1. Manually sorting through emails is more reliable than computer-aided searches for finding emails in my inbox.	SA A U D SD
2. If I need to have a tumor in my body removed, I would choose to undergo computer-aided surgery using laser technology because computerized surgery is more reliable and safer than manual surgery.	SA A U D SD
3. People save time by using automatic teller machines (ATMs) rather than a bank teller in making transactions.	SA A U D SD
4. I do not trust automated devices such as ATMs and computerized pay stations for parking lots.	SA A U D SD
5. People who work frequently with automated devices have lower job satisfaction because they feel less involved in their job than those who work manually.	SA A U D SD
6. I feel safer depositing my money at an ATM than with a human teller.	SA A U D SD
7. I have to pay an important bill. To ensure that the bill is paid with the correct amount and on time, I would use the automatic bill pay facility on my online banking rather than pay the bill manually.	SA A U D SD
8. People whose jobs require them to work with automated systems are lonelier than people who do not work with such devices.	SA A U D SD
9. Automated systems used in modern aircraft, such as the automatic landing system, have made air journey safer.	SA A U D SD
10. ATMs provide safeguard against the inappropriate use of an individual's bank account by dishonest people.	SA A U D SD
11. Automated devices used in aviation and banking have made work easier for both employees and customers.	SA A U D SD
12. I often use automated devices.	SA A U D SD
13. People who work with automated devices have greater job satisfaction because they feel more involved than those who work manually.	SA A U D SD
14. Automated devices in medicine save time and money in the diagnosis and treatment of disease.	SA A U D SD
15. Even though the automatic cruise control in my car is set at a speed below the speed limit, I worry when I pass a police radar speed-trap in case the automatic control is not working properly.	SA A U D SD
16. Bank transactions have become safer with the introduction of computer technology for the direct deposit of checks.	SA A U D SD
17. I would rather purchase an item using a computer than have to deal with a sales representative on the phone because my order is more likely to be correct using the computer.	SA A U D SD
18. Work has become more difficult with the increase of automation in aviation and banking.	SA A U D SD
19. I do not like to use ATMs because I feel that they are sometimes unreliable.	SA A U D SD
20. I think that automated devices used in medicine, such as CAT-scans and ultrasound, provide very reliable medical diagnosis.	SA A U D SD

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Appendix G. Reading Span Task (RSPAN)

Participants will be administered a computerized version of the RSPAN task[1,2] in order to evaluate their working memory capacity as well as remove participants with potential reading-comprehension issues.

RSPAN Instructions for Automated Presentation

The experiment is broken down into 2 sections. First, participants receive practice and second, the participants perform the actual experiment. The practice sessions are further broken down into 3 sections.

The first practice is simple letter span. They see letters appear on the screen one at a time and then must recall these letters in the same order they saw them. In all experimental levels, letters remain on the screen for 800 ms. Recall consists of filling in boxes with the appropriate letters. Entering a letter or space in a box should advance the cursor to the next box. At the final box, hitting the spacebar will advance to the next slide. After each recall slide, the computer provides feedback about the number of letters correctly recalled.

Next, participants practice the sentence portion of the experiment. Participants first see a sentence (e.g., "Andy was stopped by the policeman because he crossed the yellow heaven"). Once the participant has read the sentence, they are required to answer YES or NO (did the sentence make sense). After each sentence sense verification participants are given feedback. The reading practice serves to familiarize participants with the sentence portion of the experiment as well as calculate how long it takes a given person to solve the sentence problems. Thus, it attempts to account for individual differences in the time it takes to solve reading problems. After the reading practice, the program calculates the individual's mean time required to solve the problems. This time (plus 2.5 standard deviations [SDs]) is then used as a time limit for the reading portion of the experimental session.

The final practice session has participants perform both the letter recall and reading portions together, just as they will do in the experimental block. As with traditional RSPAN, participants first see the sentence and after verifying that it makes sense or not, they see the letter to be recalled. If participants take more time to verify the sentence than their average time plus 2.5 SDs, the program automatically moves on. This serves to prevent participants from rehearsing the letters when they should

[1]Unsworth N, Heitz RP, Schrock JC, Engle RW. An automated version of the operation span task. Behav Res Meth. 2005;37:498–505.

[2]Daneman M., Carpenter PA. Individual differences in working memory and reading. J Verb Learn Verb Beh. 1980; 19(4):450-466.

be verifying the sense of the sentences. After the participant completes all of the practice sessions, the program moves them to the real trials.

The experimental trials consist of 3 trials of each set size with the set sizes ranging from 3 to 6. This makes for a total of 54 letters and 54 sentence problems. Subjects are instructed to keep their reading accuracy at or above 80% at all times. During recall, a percentage in red is presented in the upper right-hand corner. Subjects are instructed to keep a careful watch on the percentage in order to keep it above 80%. Subjects get feedback at the end of each trial. Subjects who do not finish with a reading accuracy score of 80% or better will be excused from continuing with the study.

RSPAN Timing (*may be adjusted after review)*

Sentence-verification screen: Min = none, Max = mean of practice trials +2.5 SD.

Letter presentation: 800 ms.

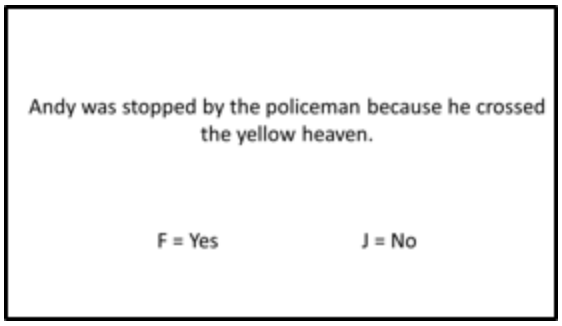
Recall screen: Min = none, Max = 2 min (there is a "Continue" button to move forward faster).

READY screen: 3 s (no keys active, cannot skip this screen).

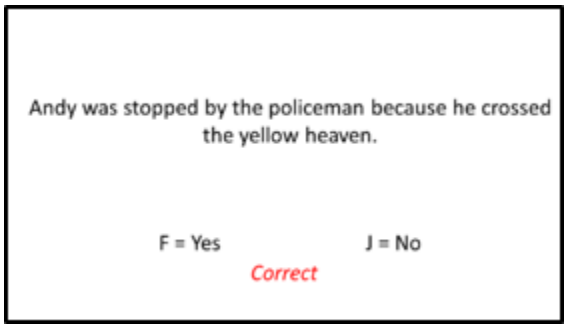
Slide Examples

Ready screen

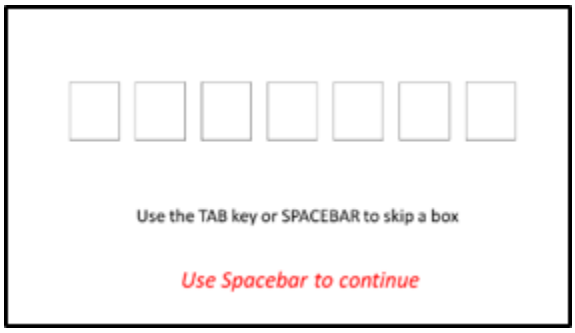
Letter screen



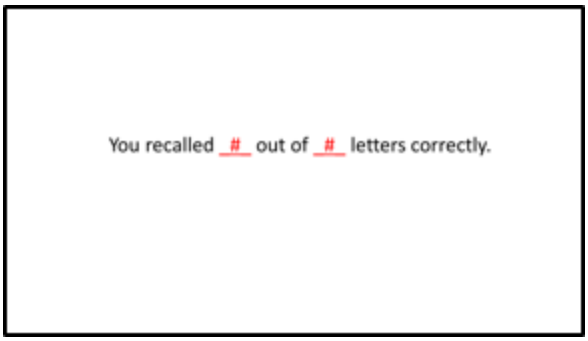
Sentence screen



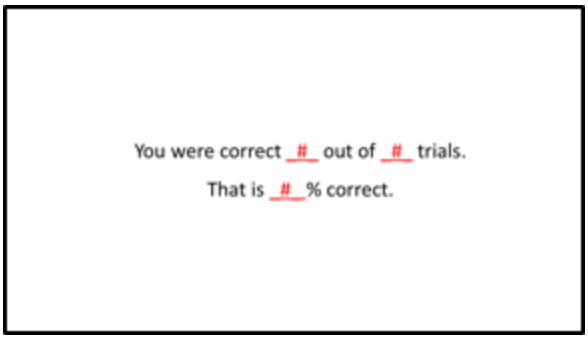
Sentence screen with feedback (for sentence practice only)



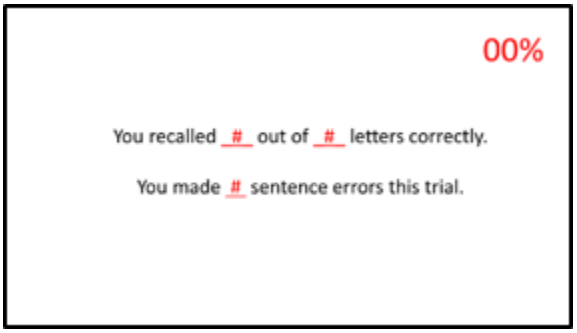
Recall screen; always 7 boxes shown



Feedback screen, letter practice



Feedback screen, sentence practice



Feedback screen, final practice and main experiment

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Appendix H. Usability Survey

This appendix appears in its original form, without editorial change.

Usability Survey

1. I made use of RoboLeader's recommendations.

Strongly DISAGREE	1	2	3	4	5	6	7	Strongly AGREE

2. I sometimes felt 'lost' using the RoboLeader display.

Strongly DISAGREE	1	2	3	4	5	6	7	Strongly AGREE

3. I do not feel the RoboLeader display was helpful in the task.

Strongly DISAGREE	1	2	3	4	5	6	7	Strongly AGREE

4. I relied heavily on the RoboLeader for the task.

Strongly DISAGREE	1	2	3	4	5	6	7	Strongly AGREE

5. Threats were visible on the screen(s) long enough to accurately detect them.

Strongly DISAGREE	1	2	3	4	5	6	7	Strongly AGREE

6. The RoboLeader display was confusing.

Strongly DISAGREE	1	2	3	4	5	6	7	Strongly AGREE

7. The RoboLeader display was annoying.

Strongly DISAGREE	1	2	3	4	5	6	7	Strongly AGREE

8. The RoboLeader display improved my performance on the task.

Strongly DISAGREE	1	2	3	4	5	6	7	Strongly AGREE

9. The RoboLeader display can be deceptive.

Strongly Strongly

DISAGREE 1 2 3 4 5 6 7 AGREE

10. The RoboLeader display sometimes behaves in an unpredictable manner.

Strongly Strongly

DISAGREE 1 2 3 4 5 6 7 AGREE

11. I am often suspicious of the RoboLeader system's intent, action, or outputs.

Strongly
Strongly

DISAGREE 1 2 3 4 5 6 7
AGREE

12. I am sometimes unsure of the RoboLeader system.

Strongly
Strongly

DISAGREE 1 2 3 4 5 6 7
AGREE

13. The RoboLeader system may have harmful effects on the task.

Strongly
Strongly

DISAGREE 1 2 3 4 5 6 7
AGREE

14. I am confident in the RoboLeader system.

Strongly
Strongly

DISAGREE 1 2 3 4 5 6 7
AGREE

15. The RoboLeader system can provide security.

Strongly
Strongly

DISAGREE 1 2 3 4 5 6 7
AGREE

16. The RoboLeader system has integrity.

Strongly DISAGREE	1	2	3	4	5	6	7 Strongly AGREE

17. The RoboLeader system is dependable.

Strongly DISAGREE	1	2	3	4	5	6	7 Strongly AGREE

18. The RoboLeader system is consistent.

Strongly DISAGREE	1	2	3	4	5	6	7 Strongly AGREE

19. I can trust the RoboLeader system.

Strongly DISAGREE	1	2	3	4	5	6	7 Strongly AGREE

20. I am familiar with the RoboLeader display.

Strongly DISAGREE	1	2	3	4	5	6	7 Strongly AGREE

Appendix I. Informed Consent

This appendix appears in its original form, without editorial change.

ARL ARMY RESEARCH LABORATORY
IRB Approved 30 June 2015

Informed Consent Form

Army Research Laboratory, Human Research & Engineering Directorate
Orlando, FL 32826

Title of Project: Transparency of automation reasoning and its effect on automation-induced complacency.

Project Number: 14-043

Sponsor: Army Research Laboratory

Principal Investigator

Name: Julia Wright
Division: Human Factors Integration Division
Branch: Information Systems Branch
Phone Number: (407) 208-3348 (DSN 970)
Email: Julia.l.wright8.civ@mail.mil

You are being asked to join a research study. This consent form explains the research study and your part in it. Please read this form carefully before you decide to take part. You can take as much time as you need. Please ask questions at any time about anything you do not understand. You are a volunteer. If you join the study, you can change your mind later. You can decide not to take part now or you can quit at any time later on.

Location of Research:

University of Central Florida Institute for Simulation and Technology, 3100 Technology Pkwy (Partnership II building), Orlando, FL 32826.

Purpose of the Study:

The purpose of this study is to determine how understanding the reasoning behind an autonomous agents' suggestions affects decision-making and performance. You will play the role of vehicle commander of a manned ground vehicle (MGV), guiding your convoy through an urban environment. In addition to the MGV, you will have an unmanned ground vehicle (UGV) and an unmanned aerial system (UAV) under your control. While supervising the robots, you will also try to maintain awareness of the surroundings of your own vehicle.

Procedures to be followed:

First, you will fill out a demographics questionnaire and complete a complete a working memory capacity test (RSPAN) and a brief color vision evaluation. The score on the RSPAN and color vision tests will determine your eligibility to continue with the experiment. After completing the RSPAN, you will complete

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some surveys that will assess your attentional control, trait trust in automation, and complacency potential. After these surveys, you will complete two tests which measure your spatial ability. After these tests, you will receive training on the experimental tasks. Your task will be to supervise a convoy of these three vehicles (your own MGV, the UAV, and the UGV) as it moves along a predetermined route from point A to point B. If route revisions are required, the autonomous agent will automatically suggest a new route, however you will have access to the information that the agent has and will need to agree or disagree with the proposed route changes. The autonomous agent will not always recommend the best route. There will be three experimental scenarios. You will learn how to differentiate between insurgents and civilians, and what to do once you detect targets.

The preliminary session (questionnaires and tests) and training will last about 1.5 hours, which will be followed by the experimental session, which will consist of three scenarios and will last about 1.5 hrs. In the experimental scenarios, you will supervise a convoy as it travels through an urban environment. You will try to find targets that are in your immediate environment as well. After completing three scenarios, you will assess your workload by completing a workload questionnaire developed by NASA (NASA-TLX) and complete the usability and trust survey. There will be a 2-minute break between scenarios. You can take longer breaks if necessary. During the experimental session, we will measure your eye movement (where you look at on the screen) using eye tracking equipment. A camera will be used to measure your eye movement; however, only aggregate eye movement data from all the participants will be reported in reports and presentations on the experiment. Your individual data will not be made public. There will not be any video recording of your eyes and face. A calibration process will take place prior to the training session and each scenario.

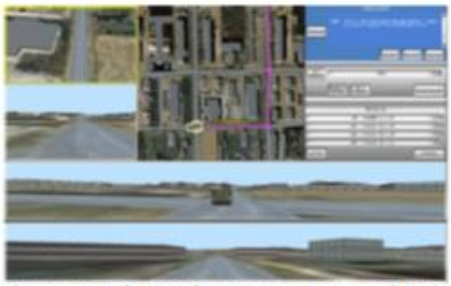

Figure 1. RoboLeader Operator Control Unit.

Discomforts and Risks:

There is minimal risk associated with using simulators such as the one used in this study that is no greater than normal use of a computer.

Benefits:

There are no personal benefits for you for taking part in this study. The results of this study might help us understand how access to agent reasoning affects human performance when interacting with multiple semi-autonomous robots for reconnaissance missions in a multi-tasking environment.

Compensation for Participation:

You will receive your choice of compensation: either payment ($15/hr) or Sona Credit at the rate of 1

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credit/hour for taking part in this experiment. You will receive at least 1 hour payment for participating. You must take all compensation in the same method, and will not be allowed to change compensation method once payment has been delivered. You cannot be paid if you are a member of the military, a civilian employee of the U.S. Government, or a family member of an employee of the Human Research & Engineering Directorate.

You will be paid cash by the UCF-IST Prodigy lab payment clerk. You will be given instructions how to receive payment upon completion of the study.

Duration: It will take about 3.5 hours for you to take part in this study.

Confidentiality:

Your participation in this research is confidential. The data will be stored and secured in a locked file cabinet in the Principal Investigator's office. Data with no identifying information (i.e., your name will not be associated with your data) will be transferred to a password-protected computer for data analysis. After the data is put in the computer file, the paper copies of the data will be shredded. This consent form will be sent to the Army Research Laboratory's Institution Review Board, where it will be retained in a secure location for a minimum of three years.

In the event of a publication or presentation resulting from the research, no personally identifiable information will be shared. Publication of the results of this study in a journal, technical report, or presentation at a meeting will not reveal personally identifiable information. The research staff will protect your data from disclosure to people not connected to this study. However, complete confidentiality cannot be guaranteed because officials of the U.S. Army Human Research Protections Office and the Army Research Laboratory's Institutional Review Board are permitted by law to inspect the records obtained in this study to insure compliance with laws and regulations covering experiments using human subjects.

Participation terminated by the investigator:

If you are unable to demonstrate sufficient ability in task performance at the end of your training, participation will be terminated by the investigator.

Consequences of withdrawal:

You may end your participation in the study at any time and there will be no penalty for withdrawing from the study. If in the rare event you ask to stop the study because you do not feel well, you will be asked to remain at the site until you feel better. You will be paid $15.00 an hour for the amount of time you participated in the study, with a minimum of one hour paid.

Contact Information for Additional Questions:

You have the right to obtain answers to any questions you might have about this research both while you take part in the study and after you leave the research site. Please contact anyone listed at the top of the first page of this consent form for more information about this study. You may also contact the Institution Review Board, at (410) 278-5928 with questions, complaints, or concerns about this research or if you feel this study has harmed you. They can also answer questions about your rights as a research participant. You may also call this number if you cannot reach the research team or wish to talk to someone else.

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Voluntary Participation:

Your decision to be in this research is voluntary. You can stop at any time. You do not have to answer any questions you do not want to answer. Refusal to take part in or withdrawing from this study will involve no penalty or loss of benefits you would receive by staying in it.

Military personnel cannot be punished under the Uniform Code of Military Justice for choosing not to take part in or withdrawing from this study, and cannot receive administrative sanctions for choosing not to participate.

Civilian employees of the U.S. Government or contractors cannot receive administrative sanctions for choosing not to participate in or withdrawing from this study.

You must be 18 years of age or older to take part in this research study. If you agree to take part in this research study based on the information outlined above, please sign your name and the date below.

You will be given a copy of this consent form for your records.

_____ _____

Participant Signature Date

_____ _____

Person Obtaining Consent Date

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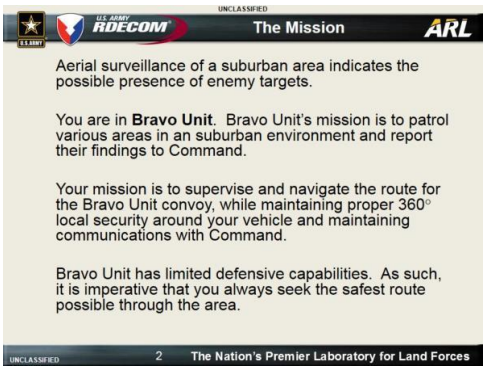
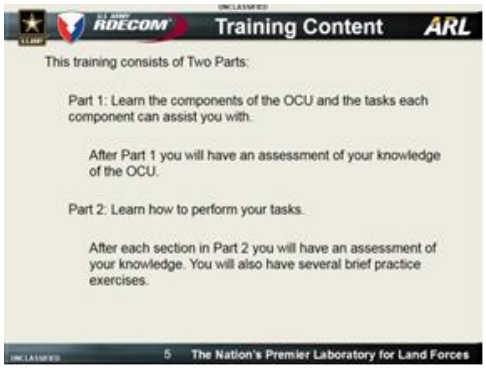
Appendix J. Training Materials

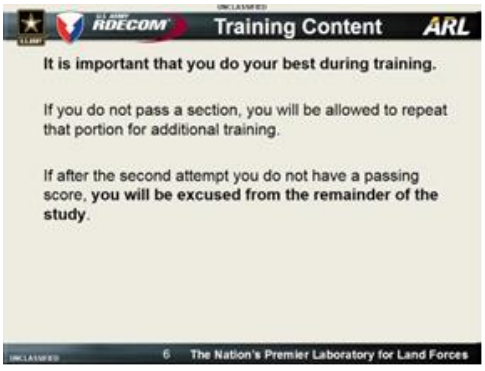
This appendix appears in its original form, without editorial change.

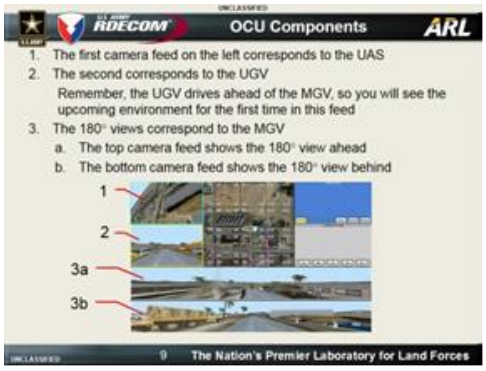
Experiment 1 Training Slides

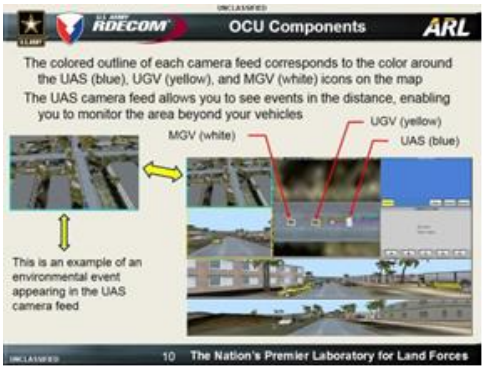
Slides are common across ARTs unless otherwise noted.



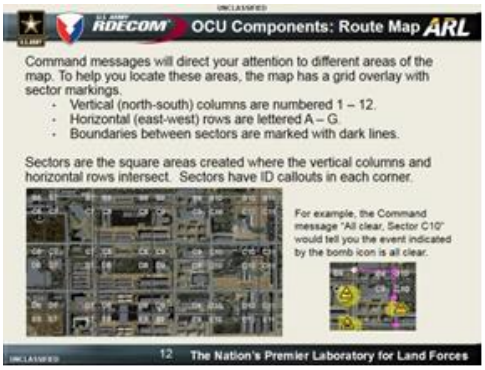





OCU Components
1. The first camera feed on the left corresponds to the UAS
2. The second corresponds to the UGV
Remember, the UGV drives ahead of the MGV, so you will see the upcoming environment for the first time in this feed
3. The 180° views correspond to the MGV
a. The top camera feed shows the 180° view ahead
b. The bottom camera feed shows the 180° view behind
1
2
3a
3b
9 The Nation's Premier Laboratory for Land Forces


OCU Components
The colored outline of each camera feed corresponds to the color around the UAS (blue), UGV (yellow), and MGV (white) icons on the map
The UAS camera feed allows you to see events in the distance, enabling you to monitor the area beyond your vehicles
MGV (white)
UGV (yellow)
UAS (blue)
This is an example of an environmental event appearing in the UAS camera feed
10 The Nation's Premier Laboratory for Land Forces


OCU Components: Route Map
The upper center window is the route map
The route map is an aerial view of the operational area
• The map allows you to maintain awareness of where your vehicles are along the route, and allows you to plan new routes when necessary.
11 The Nation's Premier Laboratory for Land Forces


OCU Components: Route Map
Command messages will direct your attention to different areas of the map. To help you locate these areas, the map has a grid overlay with sector markings.
• Vertical (north-south) columns are numbered 1 – 12.
• Horizontal (east-west) rows are lettered A – G.
• Boundaries between sectors are marked with dark lines.
Sectors are the square areas created where the vertical columns and horizontal rows intersect. Sectors have ID callouts in each corner.
For example, the Command message "All clear, Sector C10" would tell you the event indicated by the bomb icon is all clear.
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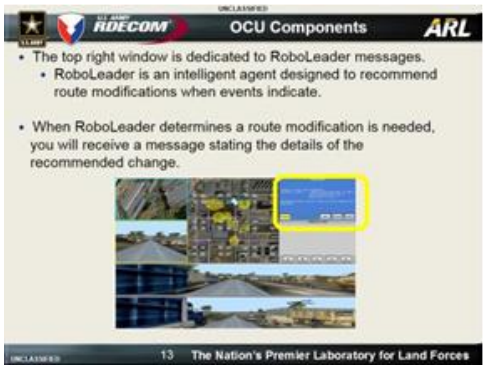
OCU Components
• The top right window is dedicated to RoboLeader messages.
• RoboLeader is an intelligent agent designed to recommend route modifications when events indicate.
• When RoboLeader determines a route modification is needed, you will receive a message stating the details of the recommended change.
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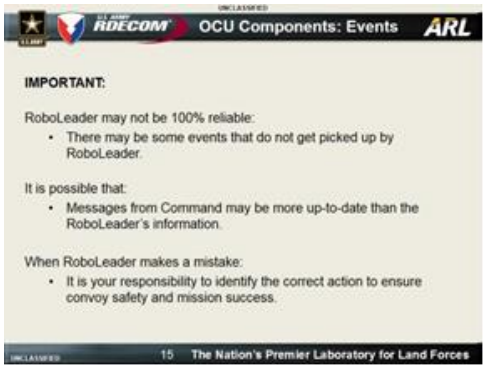
OCU Components
• The right center window is the communications window, which is used to communicate with Command.
• Incoming messages from Command appear in this window.
• You will see messages to your unit, Bravo, as well as messages to other units in the area.
• Command will also ask for information, which you will answer using the buttons below this window.
14 The Nation's Premier Laboratory for Land Forces


OCU Components: Events
IMPORTANT:
RoboLeader may not be 100% reliable:
• There may be some events that do not get picked up by RoboLeader.
It is possible that:
• Messages from Command may be more up-to-date than the RoboLeader's information.
When RoboLeader makes a mistake:
• It is your responsibility to identify the correct action to ensure convoy safety and mission success.
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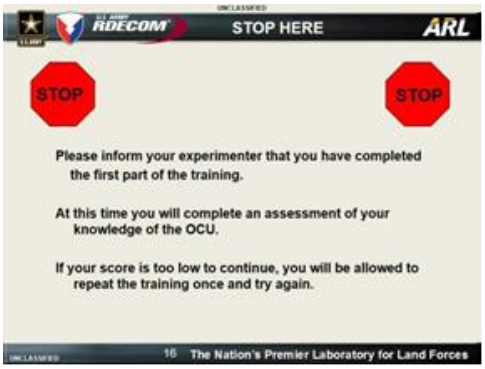
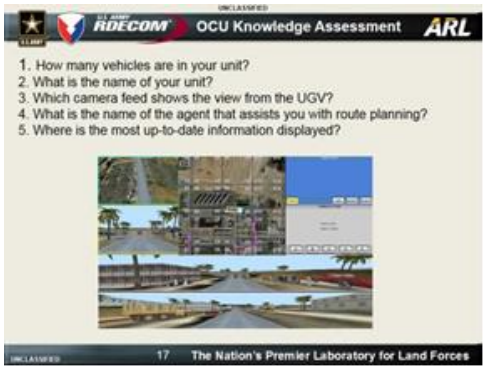

STOP HERE
STOP
STOP
Please inform your experimenter that you have completed the first part of the training.
At this time you will complete an assessment of your knowledge of the OCU.
If your score is too low to continue, you will be allowed to repeat the training once and try again.
16 The Nation's Premier Laboratory for Land Forces


OCU Knowledge Assessment
1. How many vehicles are in your unit?
2. What is the name of your unit?
3. Which camera feed shows the view from the UGV?
4. What is the name of the agent that assists you with route planning?
5. Where is the most up-to-date information displayed?
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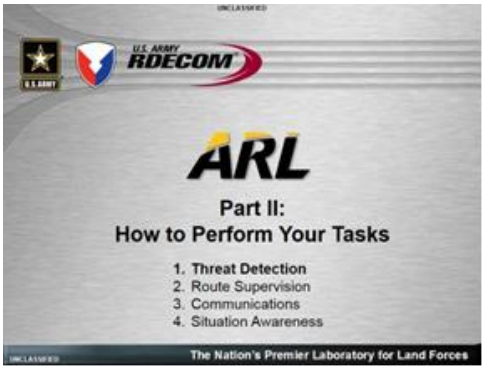
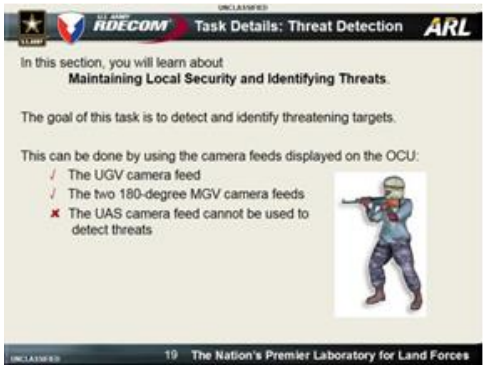

Part II:
How to Perform Your Tasks
1. Threat Detection
2. Route Supervision
3. Communications
4. Situation Awareness
The Nation's Premier Laboratory for Land Forces


Task Details: Threat Detection
In this section, you will learn about
Maintaining Local Security and Identifying Threats.
The goal of this task is to detect and identify threatening targets.
This can be done by using the camera feeds displayed on the OCU:
√ The UGV camera feed
√ The two 180-degree MGV camera feeds
✘ The UAS camera feed cannot be used to detect threats
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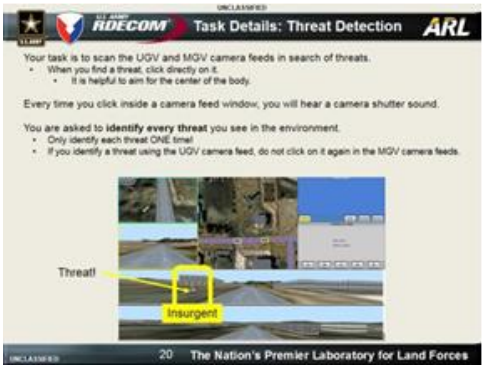
Task Details: Threat Detection
Your task is to scan the UGV and MGV camera feeds in search of threats.
When you find a threat, click directly on it.
It is helpful to aim for the center of the body.
Every time you click inside a camera feed window, you will hear a camera shutter sound.
You are asked to identify every threat you see in the environment.
Only identify each threat ONE time!
If you identify a threat using the UGV camera feed, do not click on it again in the MGV camera feeds.
Threat!
Insurgent
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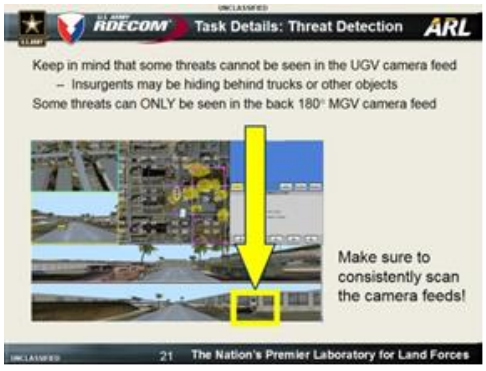
Task Details: Threat Detection
Keep in mind that some threats cannot be seen in the UGV camera feed
– Insurgents may be hiding behind trucks or other objects
Some threats can ONLY be seen in the back 180° MGV camera feed
Make sure to consistently scan the camera feeds!
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Task Details: Threat Detection
You will encounter three types of people:
• Friendly Soldiers
• Friendly Civilians
• Armed Civilians (Insurgents)
You must identify and report all armed civilians.
The following slides will show representations of each type
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Identifying Targets: Friendly Soldiers
Friendly Soldier Characteristics:
• Variety of Light camouflage uniforms
• Holding weapon
• Wearing helmet
No Action Necessary
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Identifying Targets: Friendly Soldiers
No Action Necessary
24 The Nation's Premier Laboratory for Land Forces


RDECOM
Identifying Targets: Friendly Soldiers
ARL
No Action Necessary
25 The Nation's Premier Laboratory for Land Forces


RDECOM
Identifying Targets: Friendly Civilians
ARL
Friendly Civilian Characteristics:
• Civilian clothing
• No weapon in hand
No Action Necessary
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RDECOM
Identifying Targets: Friendly Civilians
ARL
No Action Necessary
27 The Nation's Premier Laboratory for Land Forces


RDECOM
Identifying Targets: Friendly Civilians
ARL
Friendly Civilian Characteristics:
• Civilian clothing
• No weapon in hand
No Action Necessary
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RDECOM
Identifying Targets: Armed Civilians
ARL
Armed Civilian (Insurgent) Characteristics:
• Holding weapon
• Casual clothing
• Most will have masked face
Must Identify the Threat!
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RDECOM
Identifying Targets: Armed Civilians
ARL
Must Identify the Threat!
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RDECOM
Identifying Targets: Armed Civilians
ARL
Must Identify the Threat!
31 The Nation's Premier Laboratory for Land Forces


RDECOM
Identifying Targets: Armed Civilians
ARL
Must Identify the Threat!
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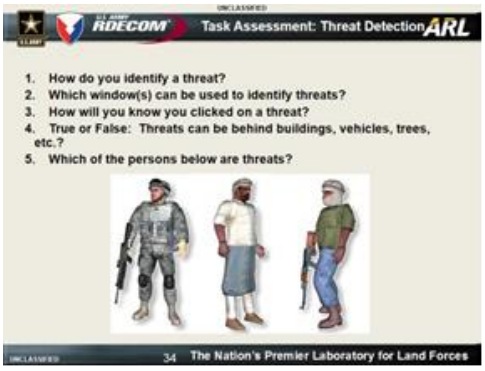
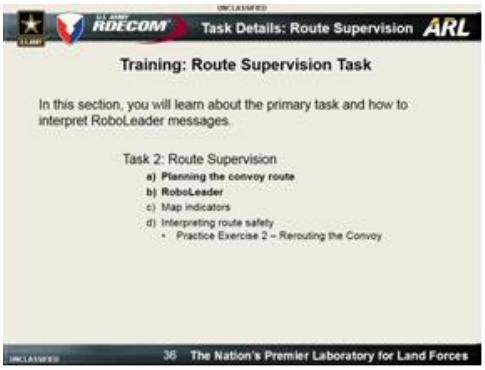
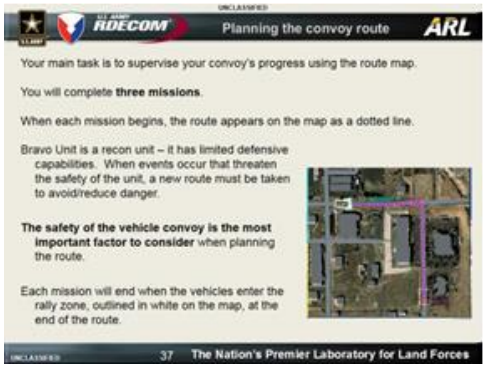
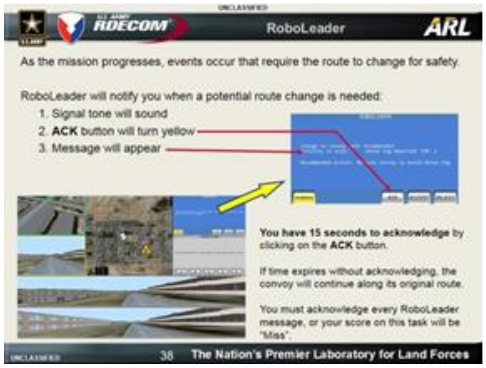


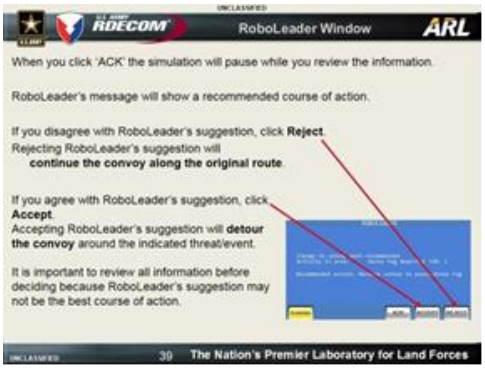


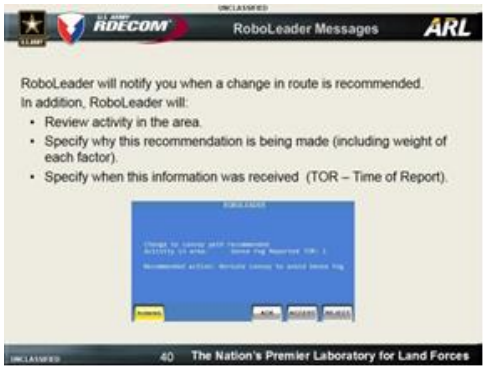


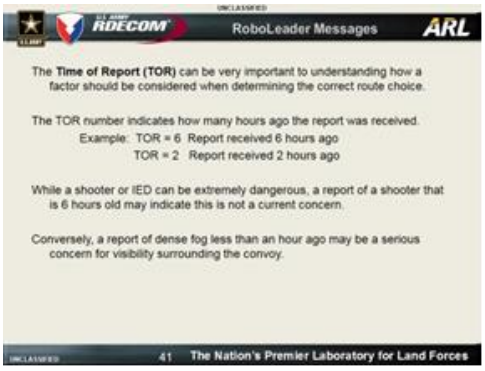
The following slides in the section "Route Supervision," parts a and b, vary according to Agent Reasoning Transparency (ART) level.

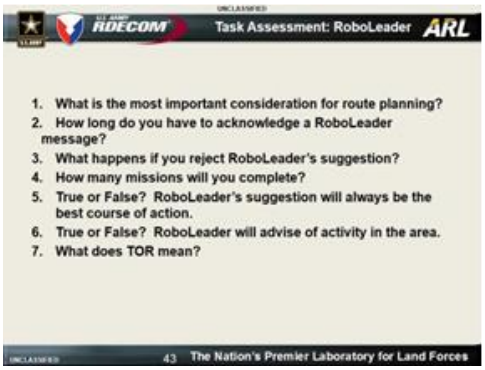
Route Supervision training slides, ART 3



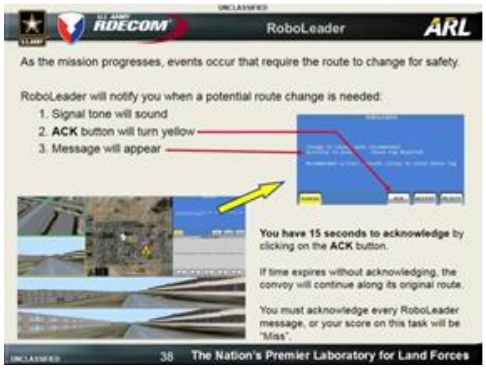


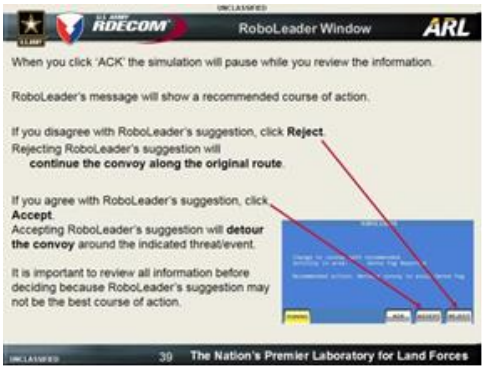


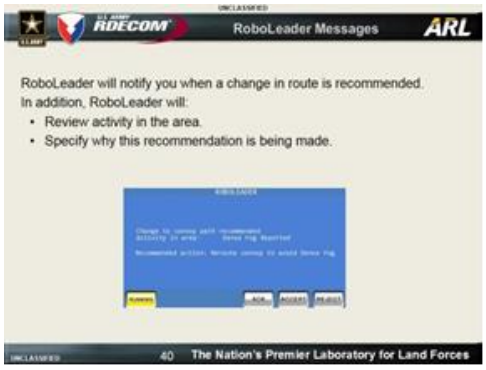


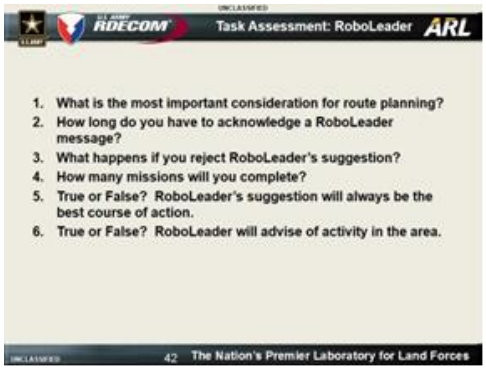


Route Supervision training slides, ART 2

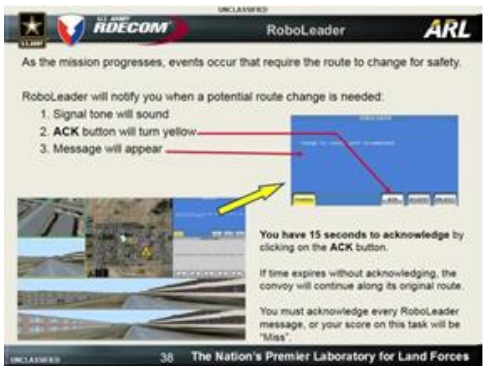


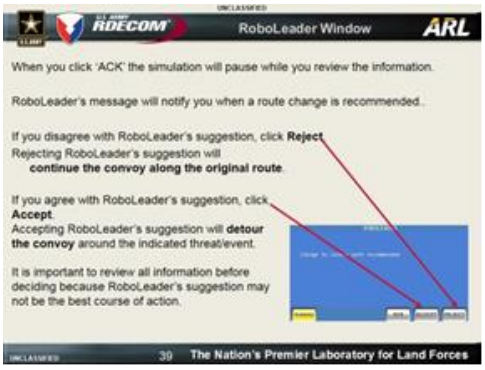


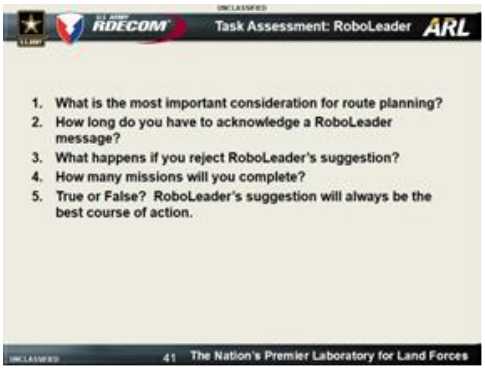




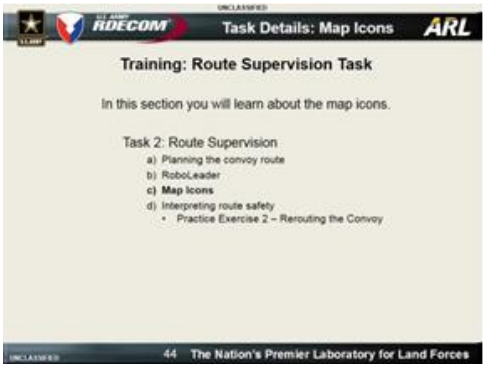
Route Supervision training slides, ART 1

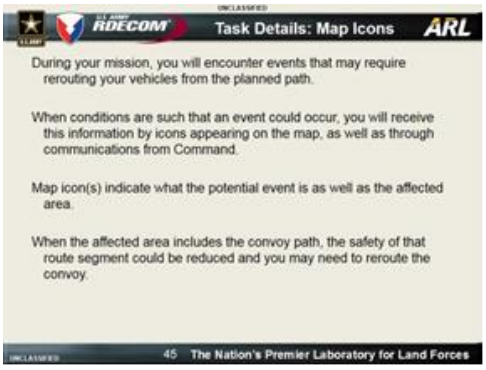


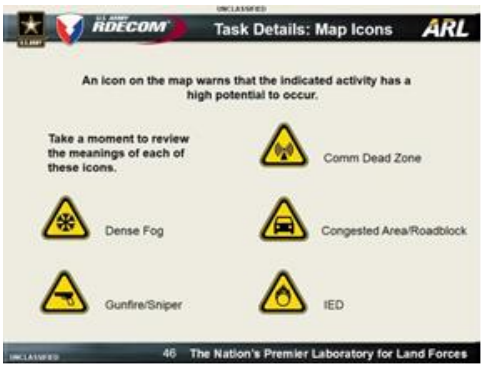


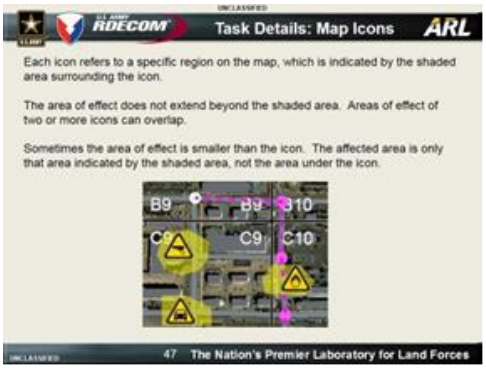


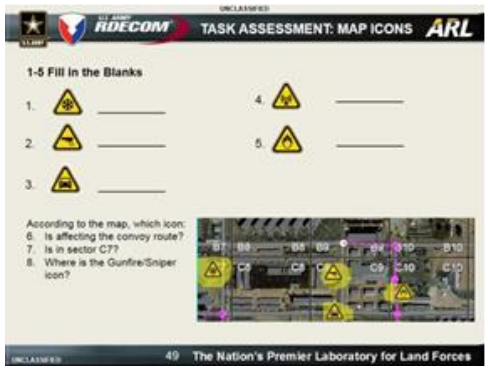
The following slides are common to all ART levels.

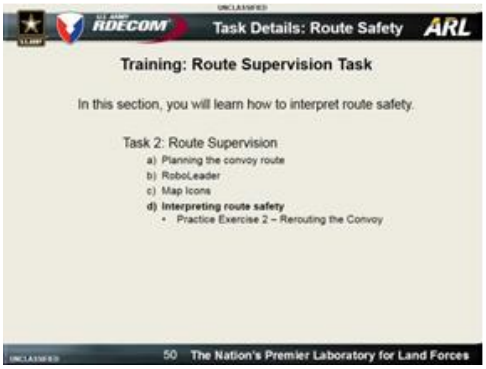


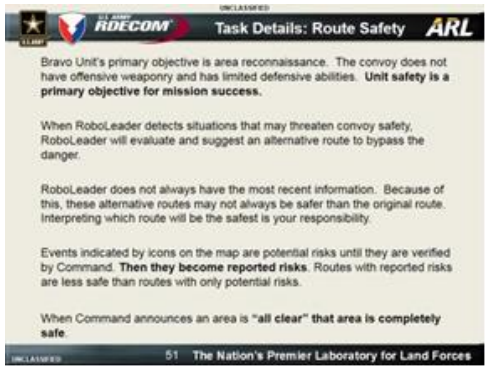


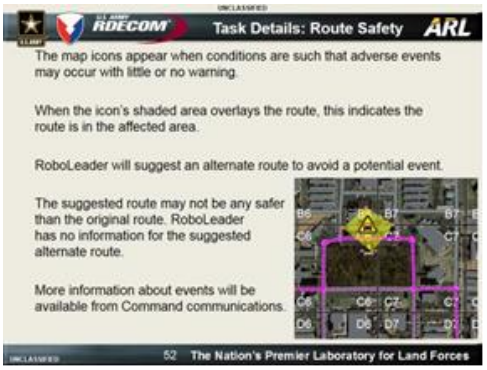











RDECOM
Task Details: Route Safety
ARL
The map icons appear when conditions are such that adverse events may occur with little or no warning.
When the icon's shaded area overlays the route, this indicates the route is in the affected area.
RoboLeader will suggest an alternate route to avoid a potential event.
The suggested route may not be any safer than the original route. RoboLeader has no information for the suggested alternate route.
More information about events will be available from Command communications.
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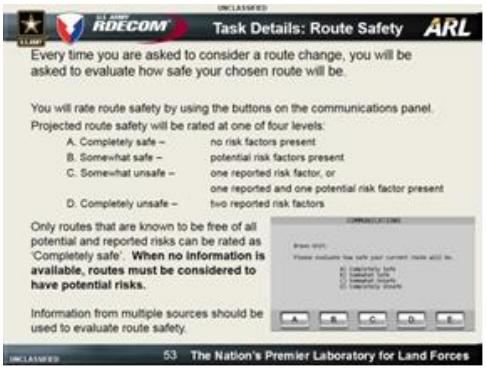
RDECOM
Task Details: Route Safety
ARL
Every time you are asked to consider a route change, you will be asked to evaluate how safe your chosen route will be.
You will rate route safety by using the buttons on the communications panel.
Projected route safety will be rated at one of four levels:
A. Completely safe – no risk factors present
B. Somewhat safe – potential risk factors present
C. Somewhat unsafe – one reported risk factor, or one reported and one potential risk factor present
D. Completely unsafe – two reported risk factors
Only routes that are known to be free of all potential and reported risks can be rated as 'Completely safe'. When no information is available, routes must be considered to have potential risks.
Information from multiple sources should be used to evaluate route safety.
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RDECOM
STOP HERE
ARL
STOP
STOP
Please inform your experimenter that you have completed this part of the training.
At this time you will complete an assessment of your knowledge of assessing and reporting route safety.
If your score is too low to continue, you will be allowed to repeat the training once and try again.
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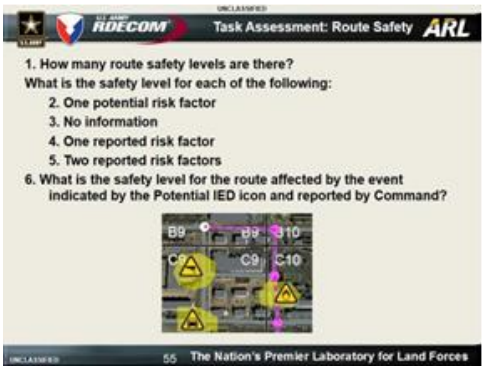
RDECOM
Task Assessment: Route Safety
ARL
1. How many route safety levels are there?
What is the safety level for each of the following:
2. One potential risk factor
3. No information
4. One reported risk factor
5. Two reported risk factors
6. What is the safety level for the route affected by the event indicated by the Potential IED icon and reported by Command?
B9
B10
C9
C10
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RDECOM
STOP HERE
ARL
STOP
STOP
Please inform your experimenter that you have completed this part of the training.
At this time you will practice the route supervision tasks.
When you complete this practice mission, you will return to these training slides.
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RDECOM
Task Details: Communication
ARL
Training: Communications
Task 3: Communication with Command
a) Incoming Messages
b) Responding to Inquiries
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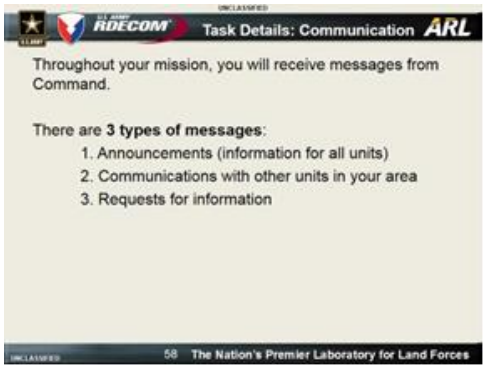
RDECOM
Task Details: Communication
ARL
Throughout your mission, you will receive messages from Command.
There are 3 types of messages:
1. Announcements (information for all units)
2. Communications with other units in your area
3. Requests for information
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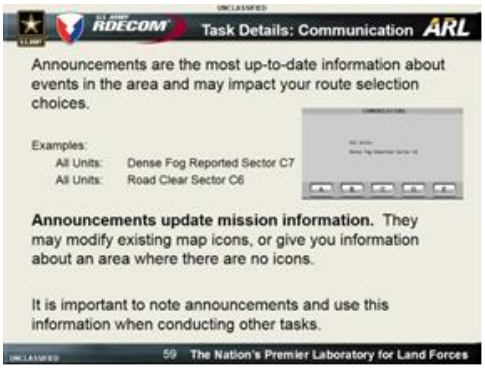
RDECOM
Task Details: Communication
ARL
Announcements are the most up-to-date information about events in the area and may impact your route selection choices.
Examples:
All Units: Dense Fog Reported Sector C7
All Units: Road Clear Sector C6
Announcements update mission information. They may modify existing map icons, or give you information about an area where there are no icons.
It is important to note announcements and use this information when conducting other tasks.
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Task Details: Communication

Communications with other units **do not affect** your unit's mission.

Examples:

Alpha Unit:	Report status
Charlie Unit:	Return to Base
Victor Unit:	Rally at Checkpoint

Task Details: Communication

Requests for information should be answered promptly using the buttons beneath the communications window.

When a request is received, you have 15 seconds to respond.

There are **three types of requests** for information:

1. Safety assessments (discussed in previous section)
2. Reports regarding route selection
3. Requests for Environment Information (discussed in following section)

Task Details: Communication

Route Selection Reports: Every time you make a route selection you will be asked to report why you made the choice that you did.

These reports will ask why you are on your current route.

Respond using the buttons at the bottom of the communications window.

There may be multiple reasons for selecting the route, so select all that apply.

It is important that you select all of the applicable reasons.

STOP HERE

STOP STOP

Please inform your experimenter that you have completed this part of the training.

At this time you will complete an assessment of your knowledge of communications.

If your score is too low to continue, you will be allowed to repeat the training once and try again.

Task Assessment: Communications

1. **How many types of messages are there?**
2. **What are the types of messages?**
3. **Which type of messages do not affect your unit's mission?**
4. **How many types of requests for information are there?**
5. **Which message type updates mission information?**

Task Details: Situation Awareness

Training: Situation Awareness

Task 4: **Situation Awareness**

Task Details: Situation Awareness

Now that you know how to supervise your routes, you will learn how to prepare for your situation awareness task.

It is important to maintain awareness of potential events in your surroundings.

Some situations allow escalation of events more readily than others. To that end, you will be asked to make note of certain objects and/or situations as you make your way along the mission route.

Throughout your missions, you will be asked questions related to current or recently passed events in the environment.

Task Details: Situation Awareness

Certain vehicles are used for enemy activity more than others. Make note of these vehicles and if people, particularly civilians, are hanging around them:

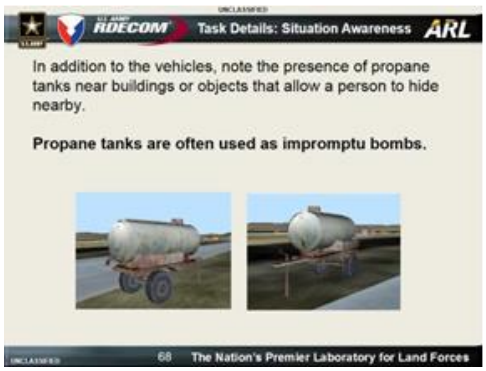
Personnel Carrier

Blue Garbage Truck

Fuel Truck

Dump Truck

Approved for public release; distribution is unlimited.


Task Details: Situation Awareness
In addition to the vehicles, note the presence of propane tanks near buildings or objects that allow a person to hide nearby.
Propane tanks are often used as impromptu bombs.
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Task Details: Situation Awareness
You should also make note of civilians who appear to be hiding, such as behind walls, vehicles, etc.
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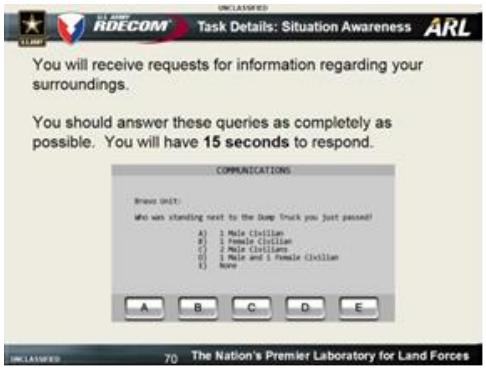
Task Details: Situation Awareness
You will receive requests for information regarding your surroundings.
You should answer these queries as completely as possible. You will have 15 seconds to respond.
COMMUNICATIONS
A
B
C
D
E
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STOP HERE
STOP
STOP
Please inform your experimenter that you have completed this part of the training.
At this time you will complete an assessment of your knowledge of the situation awareness task.
If your score is too low to continue, you will be allowed to repeat the training once and try again.
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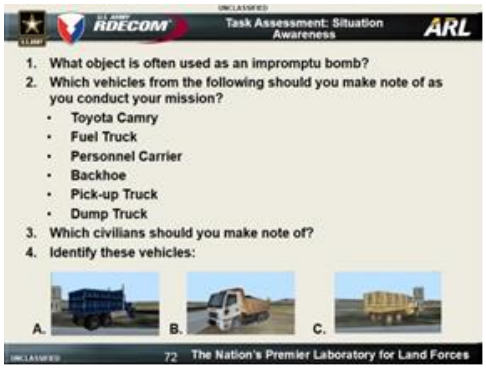
Task Assessment: Situation Awareness
1. What object is often used as an impromptu bomb?
2. Which vehicles from the following should you make note of as you conduct your mission?
Toyota Camry
Fuel Truck
Personnel Carrier
Backhoe
Pick-up Truck
Dump Truck
3. Which civilians should you make note of?
4. Identify these vehicles:
A.
B.
C.
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STOP HERE
STOP
STOP
Please inform your experimenter that you have completed this part of the training.
At this time you will practice the communication and situation awareness tasks.
When you complete this practice mission, you will return to these training slides.
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Review and Helpful Reminders
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Review
You will be conducting 3 reconnaissance missions.
You have 4 tasks:
1. Route Supervision
2. Threat Detection
3. Communications
4. Situation Awareness
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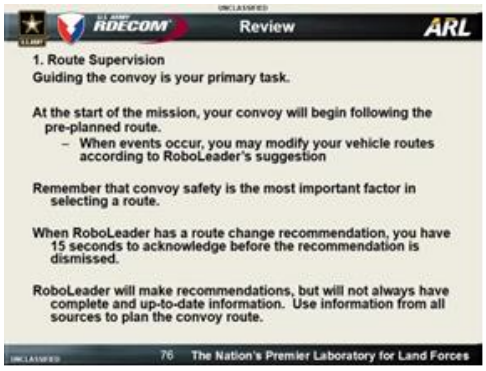
RDECOM
Review
ARL
1. Route Supervision
Guiding the convoy is your primary task.
At the start of the mission, your convoy will begin following the pre-planned route.
– When events occur, you may modify your vehicle routes according to RoboLeader's suggestion
Remember that convoy safety is the most important factor in selecting a route.
When RoboLeader has a route change recommendation, you have 15 seconds to acknowledge before the recommendation is dismissed.
RoboLeader will make recommendations, but will not always have complete and up-to-date information. Use information from all sources to plan the convoy route.
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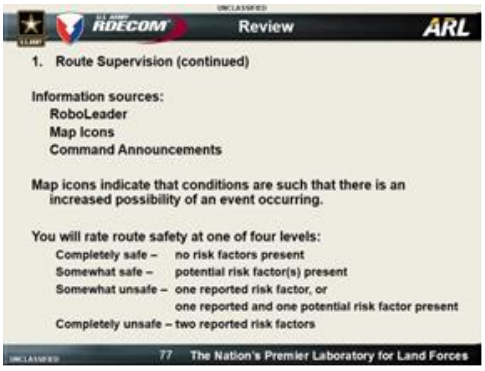
RDECOM
Review
ARL
1. Route Supervision (continued)
Information sources:
RoboLeader
Map Icons
Command Announcements
Map icons indicate that conditions are such that there is an increased possibility of an event occurring.
You will rate route safety at one of four levels:
Completely safe – no risk factors present
Somewhat safe – potential risk factor(s) present
Somewhat unsafe – one reported risk factor, or
one reported and one potential risk factor present
Completely unsafe – two reported risk factors
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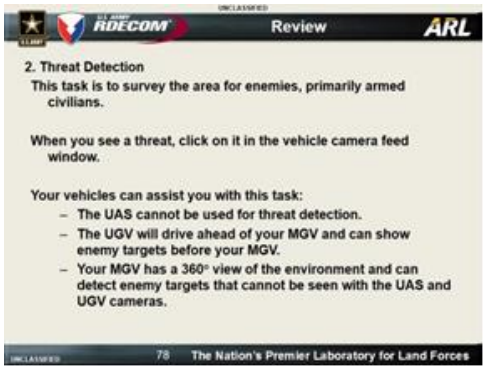
RDECOM
Review
ARL
2. Threat Detection
This task is to survey the area for enemies, primarily armed civilians.
When you see a threat, click on it in the vehicle camera feed window.
Your vehicles can assist you with this task:
– The UAS cannot be used for threat detection.
– The UGV will drive ahead of your MGV and can show enemy targets before your MGV.
– Your MGV has a 360° view of the environment and can detect enemy targets that cannot be seen with the UAS and UGV cameras.
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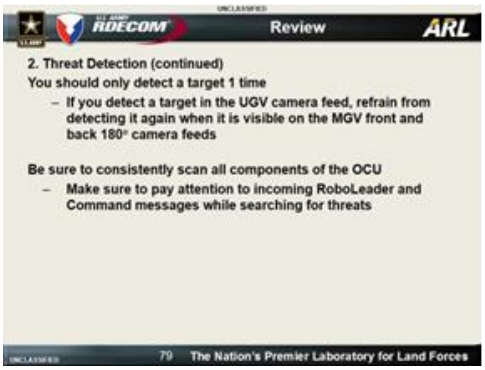
RDECOM
Review
ARL
2. Threat Detection (continued)
You should only detect a target 1 time
– If you detect a target in the UGV camera feed, refrain from detecting it again when it is visible on the MGV front and back 180° camera feeds
Be sure to consistently scan all components of the OCU
– Make sure to pay attention to incoming RoboLeader and Command messages while searching for threats
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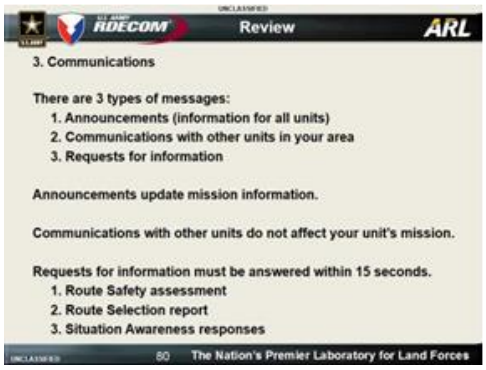
RDECOM
Review
ARL
3. Communications
There are 3 types of messages:
1. Announcements (information for all units)
2. Communications with other units in your area
3. Requests for information
Announcements update mission information.
Communications with other units do not affect your unit's mission.
Requests for information must be answered within 15 seconds.
1. Route Safety assessment
2. Route Selection report
3. Situation Awareness responses
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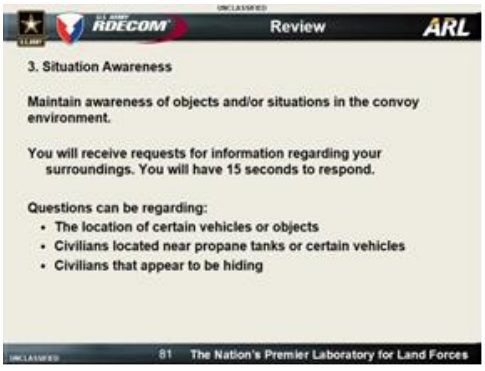
RDECOM
Review
ARL
3. Situation Awareness
Maintain awareness of objects and/or situations in the convoy environment.
You will receive requests for information regarding your surroundings. You will have 15 seconds to respond.
Questions can be regarding:
• The location of certain vehicles or objects
• Civilians located near propane tanks or certain vehicles
• Civilians that appear to be hiding
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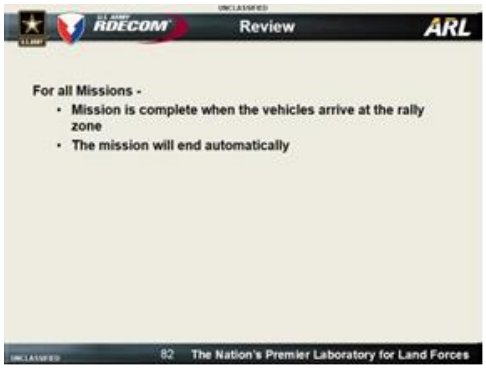
RDECOM
Review
ARL
For all Missions -
• Mission is complete when the vehicles arrive at the rally zone
• The mission will end automatically
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RDECOM
STOP HERE
ARL
STOP
STOP
Please inform your experimenter that you have completed this part of the training.
At this point, you will perform one full practice scenario with all of the task components
• Route Supervision
• Threat Detection
• Communications
• Situation Awareness
When you have completed this practice mission, you have a short break, and then will begin your first mission
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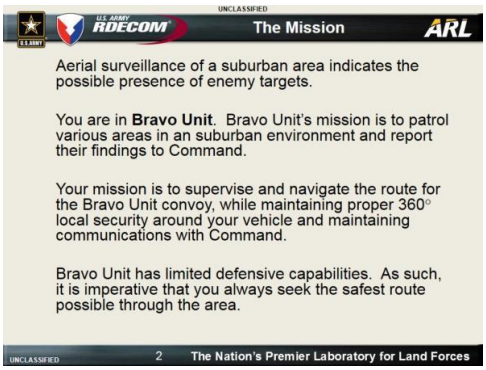
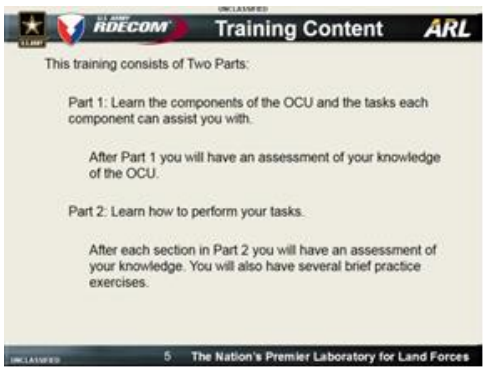
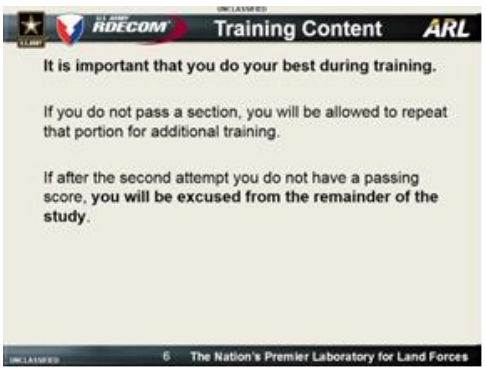
Experiment 2 Training Slides

Slides are common across ARTs unless otherwise noted.







OCU Components

1. The first camera feed on the left corresponds to the UAS
2. The second corresponds to the UGV
   Remember, the UGV drives ahead of the MGV, so you will see the upcoming environment for the first time in this feed
3. The 180° views correspond to the MGV
   a. The top camera feed shows the 180° view ahead
   b. The bottom camera feed shows the 180° view behind

OCU Components

The colored outline of each camera feed corresponds to the color around the UAS (blue), UGV (yellow), and MGV (white) icons on the map

The UAS camera feed allows you to see events in the distance, enabling you to monitor the area beyond your vehicles

OCU Components: Route Map

The upper center window is the route map

The route map is an aerial view of the operational area

- The map allows you to maintain awareness of where your vehicles are along the route, and allows you to plan new routes when necessary.

OCU Components: Route Map

Command messages will direct your attention to different areas of the map. To help you locate these areas, the map has a grid overlay with sector markings.

- Vertical (north-south) columns are numbered 1 – 12.
- Horizontal (east-west) rows are lettered A – G.
- Boundaries between sectors are marked with dark lines.

Sectors are the square areas created where the vertical columns and horizontal rows intersect. Sectors have ID callouts in each corner.

For example, the Command message "All clear, Sector C10" would tell you the event indicated by the bomb icon is all clear.

OCU Components

- The top right window is dedicated to RoboLeader messages.
  - RoboLeader is an intelligent agent designed to recommend route modifications when events indicate.
- When RoboLeader determines a route modification is needed, you will receive a message stating the details of the recommended change.

OCU Components

- The right center window is the communications window, which is used to communicate with Command.
- Incoming messages from Command appear in this window.
  - You will see messages to your unit, Bravo, as well as messages to other units in the area.
  - Command will also ask for information, which you will answer using the buttons below this window.

OCU Components: Events

IMPORTANT:

RoboLeader may not be 100% reliable:

- There may be some events that do not get picked up by RoboLeader.

It is possible that:

- Messages from Command may be more up-to-date than the RoboLeader's information.

When RoboLeader makes a mistake:

- It is your responsibility to identify the correct action to ensure convoy safety and mission success.

STOP HERE

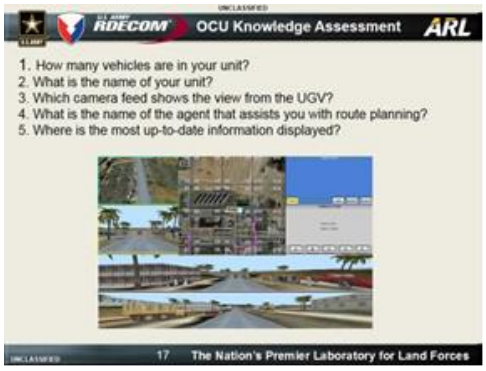
STOP STOP

Please inform your experimenter that you have completed the first part of the training.

At this time you will complete an assessment of your knowledge of the OCU.

If your score is too low to continue, you will be allowed to repeat the training once and try again.

Approved for public release; distribution is unlimited.


OCU Knowledge Assessment
1. How many vehicles are in your unit?
2. What is the name of your unit?
3. Which camera feed shows the view from the UGV?
4. What is the name of the agent that assists you with route planning?
5. Where is the most up-to-date information displayed?
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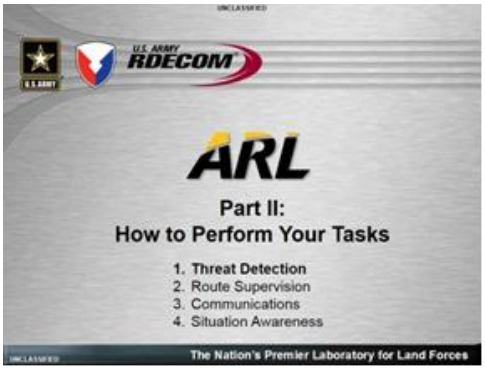
Part II:
How to Perform Your Tasks
1. Threat Detection
2. Route Supervision
3. Communications
4. Situation Awareness
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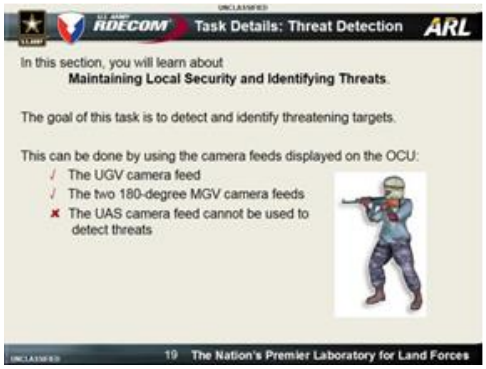
Task Details: Threat Detection
In this section, you will learn about
Maintaining Local Security and Identifying Threats.
The goal of this task is to detect and identify threatening targets.
This can be done by using the camera feeds displayed on the OCU:
√ The UGV camera feed
√ The two 180-degree MGV camera feeds
✘ The UAS camera feed cannot be used to detect threats
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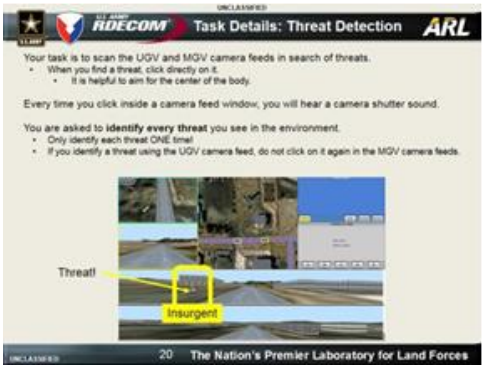
Task Details: Threat Detection
Your task is to scan the UGV and MGV camera feeds in search of threats.
When you find a threat, click directly on it.
It is helpful to aim for the center of the body.
Every time you click inside a camera feed window, you will hear a camera shutter sound.
You are asked to identify every threat you see in the environment.
Only identify each threat ONE time!
If you identify a threat using the UGV camera feed, do not click on it again in the MGV camera feeds.
Threat!
Insurgent
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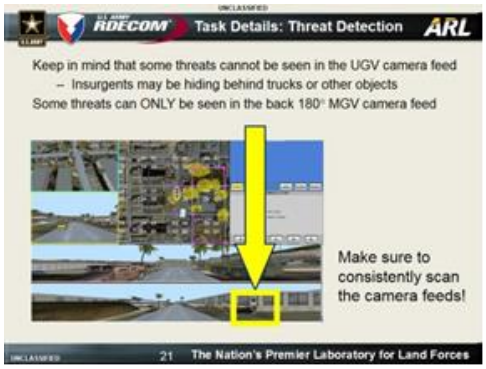
Task Details: Threat Detection
Keep in mind that some threats cannot be seen in the UGV camera feed
– Insurgents may be hiding behind trucks or other objects
Some threats can ONLY be seen in the back 180° MGV camera feed
Make sure to consistently scan the camera feeds!
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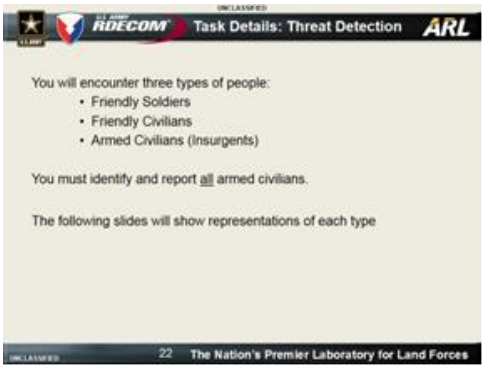
Task Details: Threat Detection
You will encounter three types of people:
• Friendly Soldiers
• Friendly Civilians
• Armed Civilians (Insurgents)
You must identify and report all armed civilians.
The following slides will show representations of each type
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Identifying Targets: Friendly Soldiers
Friendly Soldier Characteristics:
• Variety of Light camouflage uniforms
• Holding weapon
• Wearing helmet
No Action Necessary
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Identifying Targets: Friendly Soldiers
No Action Necessary
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UNCLASSIFIED
RDECOM
Identifying Targets: Friendly Soldiers
ARL
No Action Necessary
UNCLASSIFIED
25
The Nation's Premier Laboratory for Land Forces


UNCLASSIFIED
RDECOM
Identifying Targets: Friendly Civilians
ARL
Friendly Civilian Characteristics:
• Civilian clothing
• No weapon in hand
No Action Necessary
UNCLASSIFIED
26
The Nation's Premier Laboratory for Land Forces


UNCLASSIFIED
RDECOM
Identifying Targets: Friendly Civilians
ARL
No Action Necessary
UNCLASSIFIED
27
The Nation's Premier Laboratory for Land Forces


UNCLASSIFIED
RDECOM
Identifying Targets: Friendly Civilians
ARL
Friendly Civilian Characteristics:
• Civilian clothing
• No weapon in hand
No Action Necessary
UNCLASSIFIED
28
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UNCLASSIFIED
RDECOM
Identifying Targets: Armed Civilians
ARL
Armed Civilian (Insurgent) Characteristics:
• Holding weapon
• Casual clothing
• Most will have masked face
Must Identify the Threat!
UNCLASSIFIED
29
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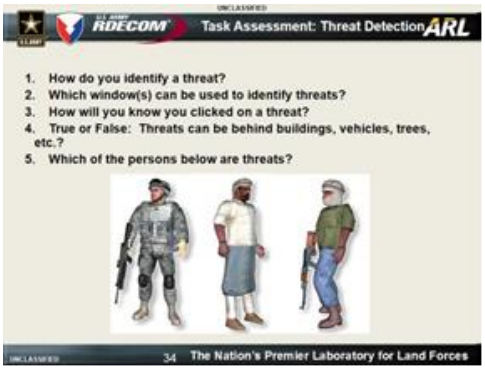
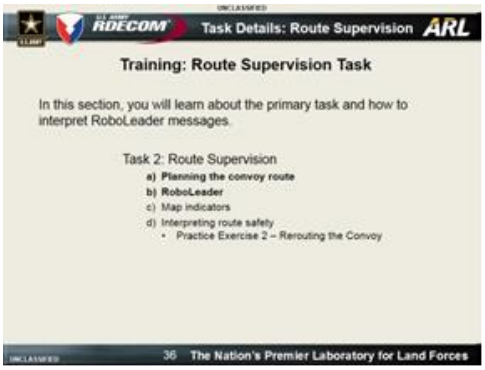
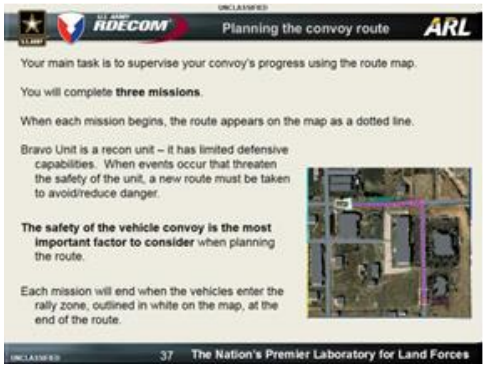
UNCLASSIFIED
RDECOM
Identifying Targets: Armed Civilians
ARL
Must Identify the Threat!
UNCLASSIFIED
30
The Nation's Premier Laboratory for Land Forces


UNCLASSIFIED
RDECOM
Identifying Targets: Armed Civilians
ARL
Must Identify the Threat!
UNCLASSIFIED
31
The Nation's Premier Laboratory for Land Forces


UNCLASSIFIED
RDECOM
Identifying Targets: Armed Civilians
ARL
Must Identify the Threat!
UNCLASSIFIED
32
The Nation's Premier Laboratory for Land Forces

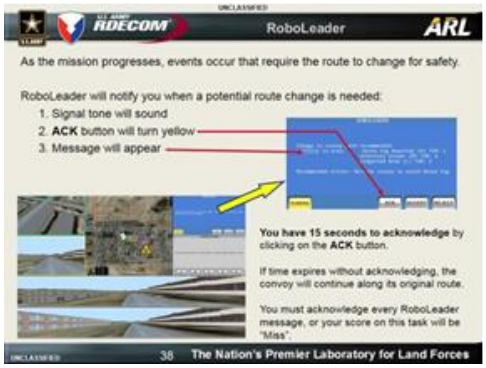


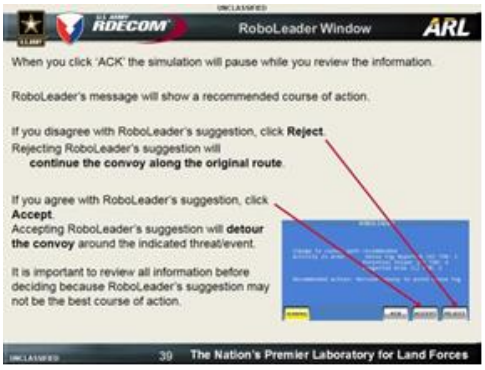


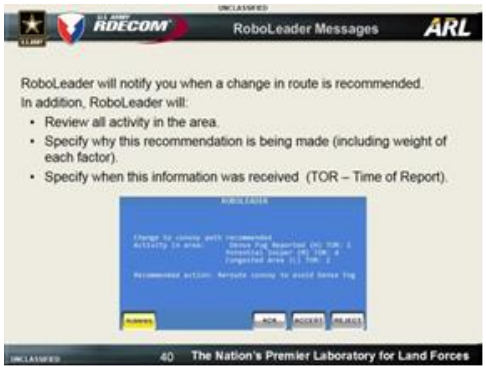


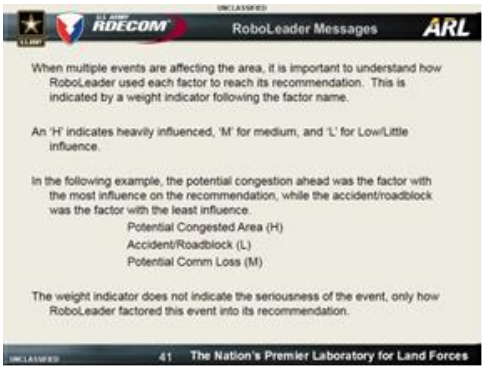
The following slides in the section "Route Supervision," parts a and b, vary according to Agent Reasoning Transparency (ART) level.

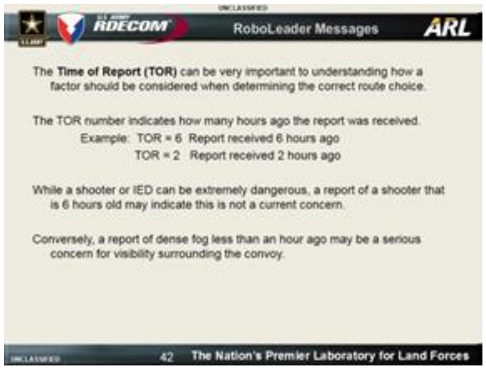
Route Supervision training slides, ART 3

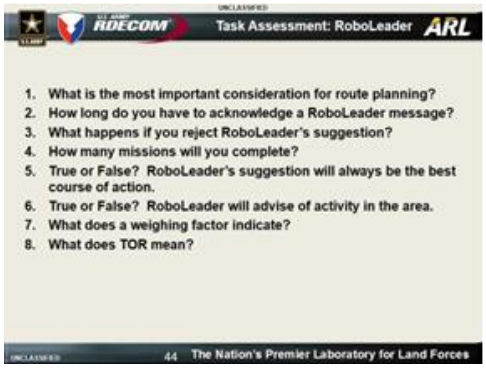




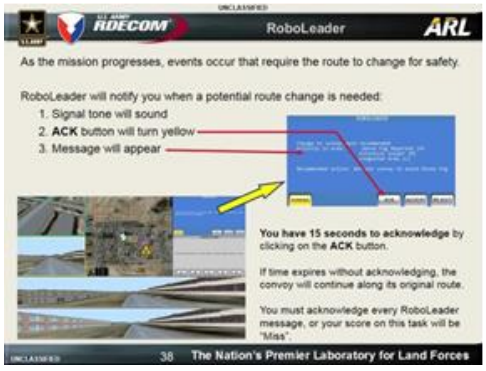


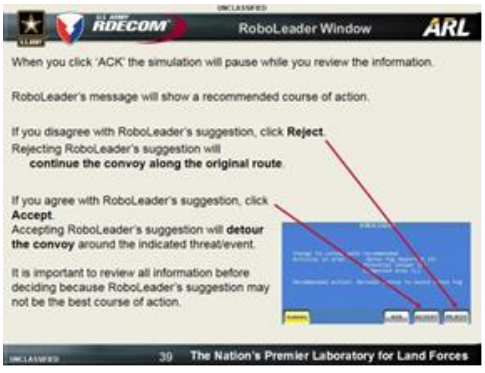


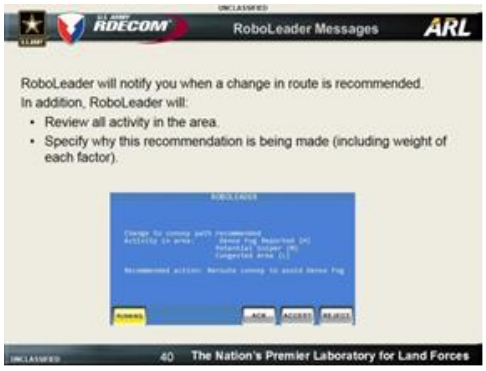


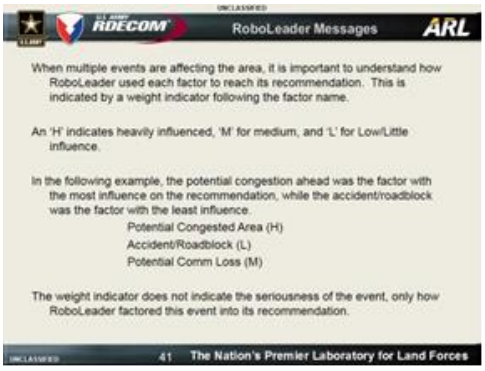


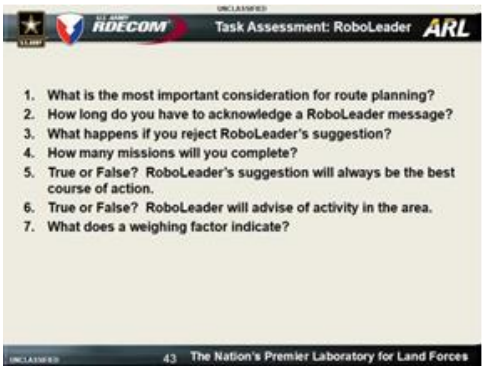
Route Supervision training slides, ART 2



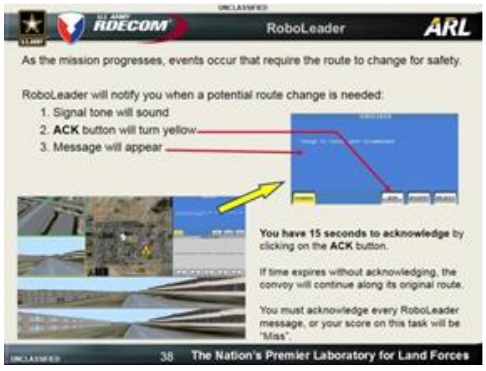


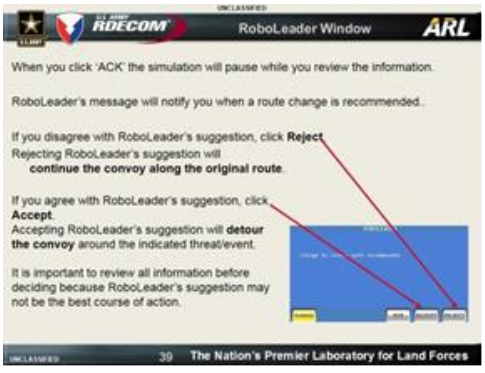


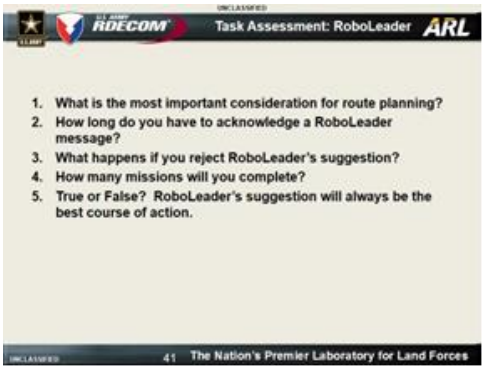




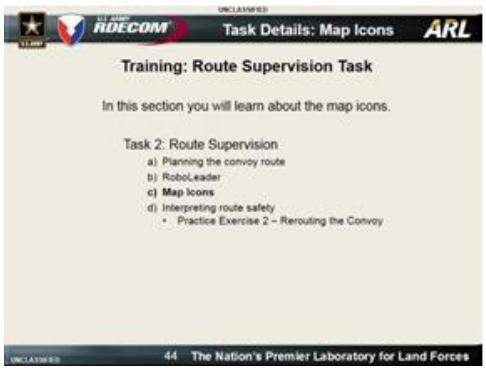
Route Supervision training slides, ART 1

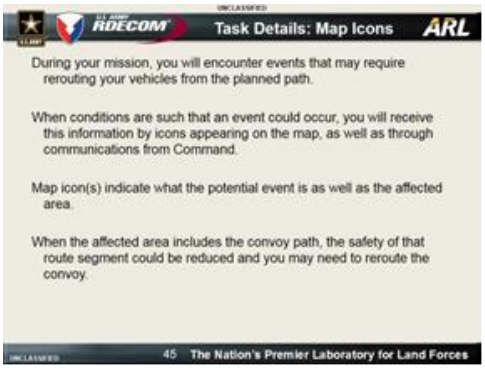


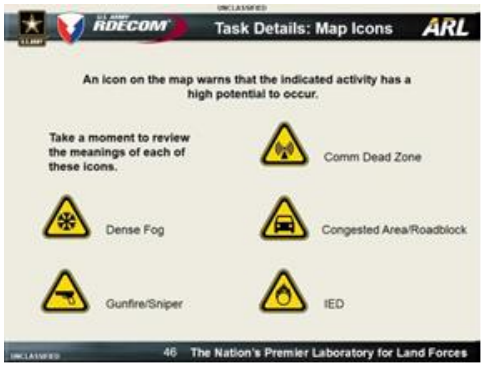


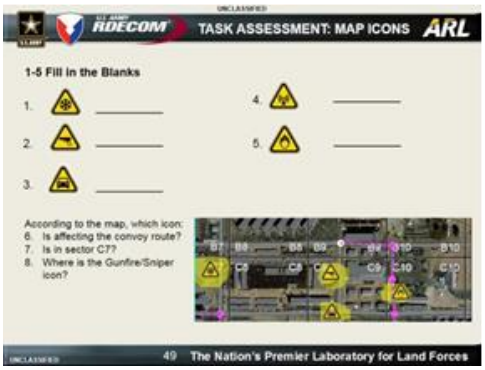


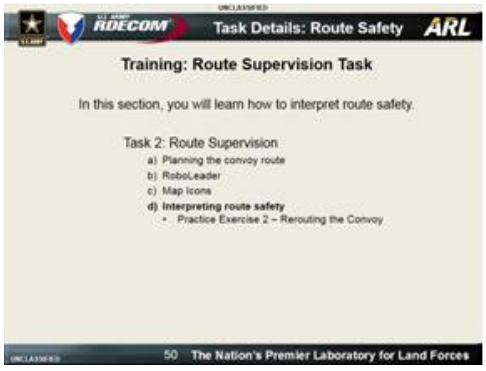
The following slides are common to all ART levels.

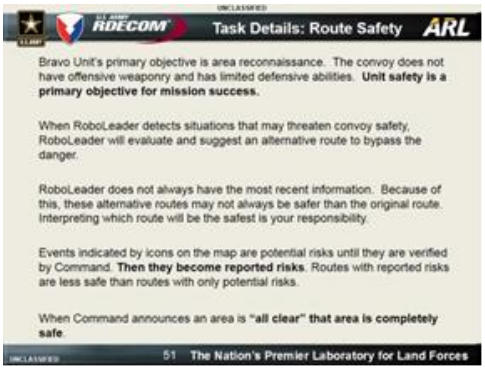


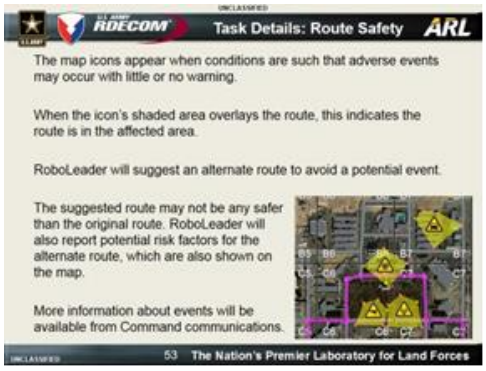











RDECOM
Task Details: Route Safety
ARL
The map icons appear when conditions are such that adverse events may occur with little or no warning.
When the icon's shaded area overlays the route, this indicates the route is in the affected area.
RoboLeader will suggest an alternate route to avoid a potential event.
The suggested route may not be any safer than the original route. RoboLeader will also report potential risk factors for the alternate route, which are also shown on the map.
More information about events will be available from Command communications.
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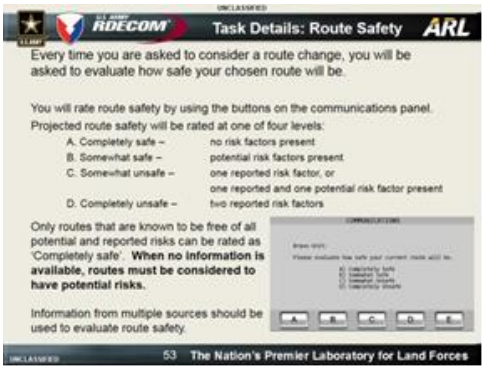
RDECOM
Task Details: Route Safety
ARL
Every time you are asked to consider a route change, you will be asked to evaluate how safe your chosen route will be.
You will rate route safety by using the buttons on the communications panel.
Projected route safety will be rated at one of four levels:
A. Completely safe – no risk factors present
B. Somewhat safe – potential risk factors present
C. Somewhat unsafe – one reported risk factor, or one reported and one potential risk factor present
D. Completely unsafe – two reported risk factors
Only routes that are known to be free of all potential and reported risks can be rated as 'Completely safe'. When no information is available, routes must be considered to have potential risks.
Information from multiple sources should be used to evaluate route safety.
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RDECOM
STOP HERE
ARL
STOP
STOP
Please inform your experimenter that you have completed this part of the training.
At this time you will complete an assessment of your knowledge of assessing and reporting route safety.
If your score is too low to continue, you will be allowed to repeat the training once and try again.
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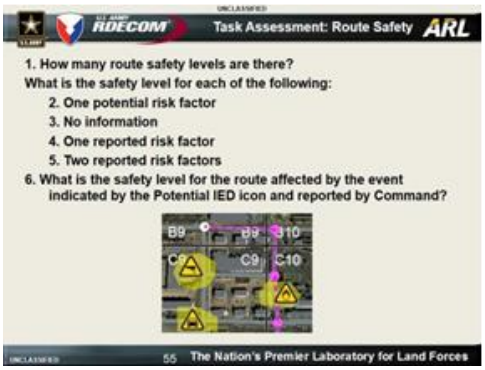
RDECOM
Task Assessment: Route Safety
ARL
1. How many route safety levels are there?
What is the safety level for each of the following:
2. One potential risk factor
3. No information
4. One reported risk factor
5. Two reported risk factors
6. What is the safety level for the route affected by the event indicated by the Potential IED icon and reported by Command?
B9
B10
C9
C10
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RDECOM
STOP HERE
ARL
STOP
STOP
Please inform your experimenter that you have completed this part of the training.
At this time you will practice the route supervision tasks.
When you complete this practice mission, you will return to these training slides.
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RDECOM
Task Details: Communication
ARL
Training: Communications
Task 3: Communication with Command
a) Incoming Messages
b) Responding to Inquiries
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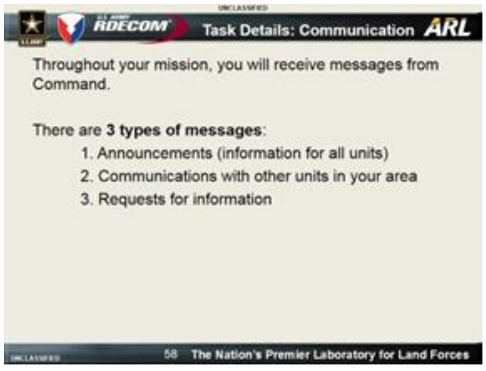
RDECOM
Task Details: Communication
ARL
Throughout your mission, you will receive messages from Command.
There are 3 types of messages:
1. Announcements (information for all units)
2. Communications with other units in your area
3. Requests for information
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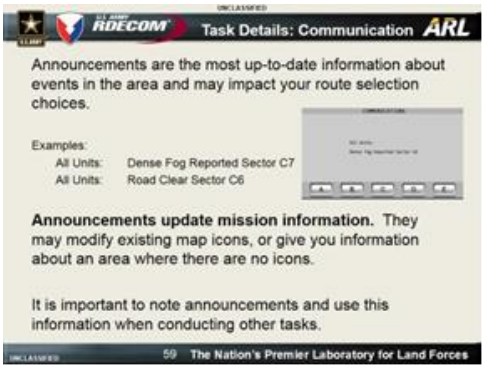
RDECOM
Task Details: Communication
ARL
Announcements are the most up-to-date information about events in the area and may impact your route selection choices.
Examples:
All Units: Dense Fog Reported Sector C7
All Units: Road Clear Sector C6
Announcements update mission information. They may modify existing map icons, or give you information about an area where there are no icons.
It is important to note announcements and use this information when conducting other tasks.
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Task Details: Communication

Communications with other units **do not affect** your unit's mission.

Examples:

Alpha Unit:	Report status
Charlie Unit:	Return to Base
Victor Unit:	Rally at Checkpoint

Task Details: Communication

Requests for information should be answered promptly using the buttons beneath the communications window.

When a request is received, you have 15 seconds to respond.

There are **three types of requests** for information:

1. Safety assessments (discussed in previous section)
2. Reports regarding route selection
3. Requests for Environment Information (discussed in following section)

Task Details: Communication

Route Selection Reports: Every time you make a route selection you will be asked to report why you made the choice that you did.

These reports will ask why you are on your current route.

Respond using the buttons at the bottom of the communications window.

There may be multiple reasons for selecting the route, so select all that apply.

It is important that you select all of the applicable reasons.

STOP HERE

STOP STOP

Please inform your experimenter that you have completed this part of the training.

At this time you will complete an assessment of your knowledge of communications.

If your score is too low to continue, you will be allowed to repeat the training once and try again.

Task Assessment: Communications

1. **How many types of messages are there?**
2. **What are the types of messages?**
3. **Which type of messages do not affect your unit's mission?**
4. **How many types of requests for information are there?**
5. **Which message type updates mission information?**

Task Details: Situation Awareness

Training: Situation Awareness

Task 4: **Situation Awareness**

Task Details: Situation Awareness

Now that you know how to supervise your routes, you will learn how to prepare for your situation awareness task.

It is important to maintain awareness of potential events in your surroundings.

Some situations allow escalation of events more readily than others. To that end, you will be asked to make note of certain objects and/or situations as you make your way along the mission route.

Throughout your missions, you will be asked questions related to current or recently passed events in the environment.

Task Details: Situation Awareness

Certain vehicles are used for enemy activity more than others. Make note of these vehicles and if people, particularly civilians, are hanging around them:

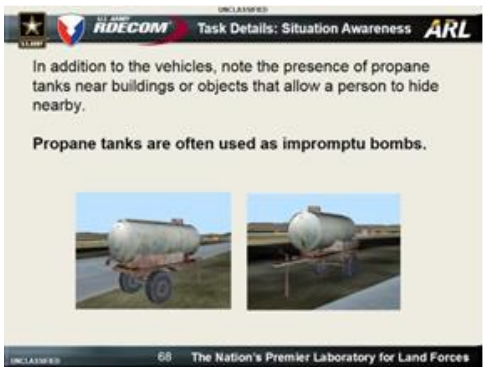
Personnel Carrier

Blue Garbage Truck

Fuel Truck

Dump Truck

Approved for public release; distribution is unlimited.


Task Details: Situation Awareness
In addition to the vehicles, note the presence of propane tanks near buildings or objects that allow a person to hide nearby.
Propane tanks are often used as impromptu bombs.
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Task Details: Situation Awareness
You should also make note of civilians who appear to be hiding, such as behind walls, vehicles, etc.
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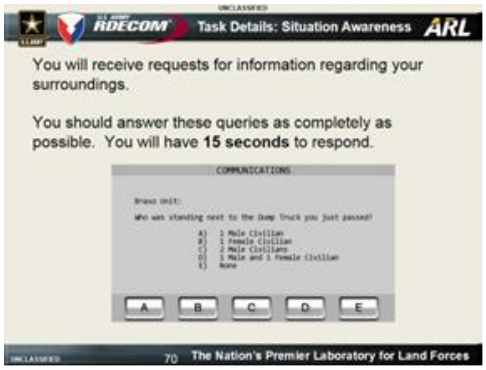
Task Details: Situation Awareness
You will receive requests for information regarding your surroundings.
You should answer these queries as completely as possible. You will have 15 seconds to respond.
COMMUNICATIONS
A
B
C
D
E
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STOP HERE
STOP
STOP
Please inform your experimenter that you have completed this part of the training.
At this time you will complete an assessment of your knowledge of the situation awareness task.
If your score is too low to continue, you will be allowed to repeat the training once and try again.
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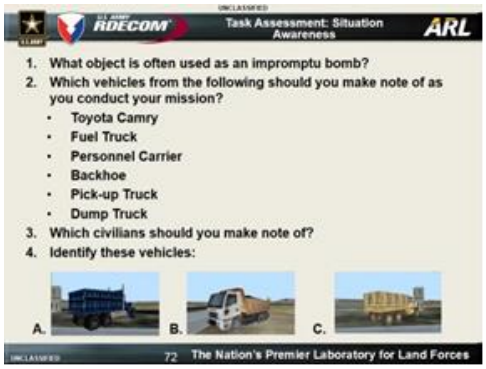
Task Assessment: Situation Awareness
1. What object is often used as an impromptu bomb?
2. Which vehicles from the following should you make note of as you conduct your mission?
Toyota Camry
Fuel Truck
Personnel Carrier
Backhoe
Pick-up Truck
Dump Truck
3. Which civilians should you make note of?
4. Identify these vehicles:
A.
B.
C.
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STOP HERE
STOP
STOP
Please inform your experimenter that you have completed this part of the training.
At this time you will practice the communication and situation awareness tasks.
When you complete this practice mission, you will return to these training slides.
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Review and Helpful Reminders
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Review
You will be conducting 3 reconnaissance missions.
You have 4 tasks:
1. Route Supervision
2. Threat Detection
3. Communications
4. Situation Awareness
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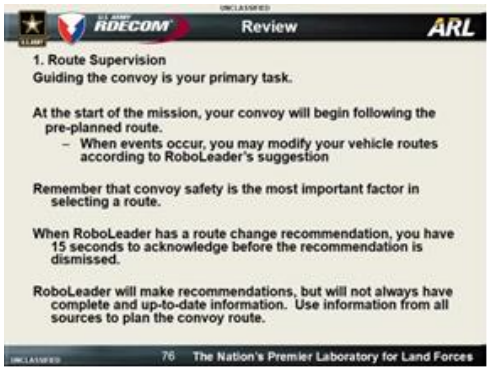
UNCLASSIFIED
RDECOM
Review
ARL
1. Route Supervision
Guiding the convoy is your primary task.
At the start of the mission, your convoy will begin following the pre-planned route.
– When events occur, you may modify your vehicle routes according to RoboLeader's suggestion
Remember that convoy safety is the most important factor in selecting a route.
When RoboLeader has a route change recommendation, you have 15 seconds to acknowledge before the recommendation is dismissed.
RoboLeader will make recommendations, but will not always have complete and up-to-date information. Use information from all sources to plan the convoy route.
UNCLASSIFIED
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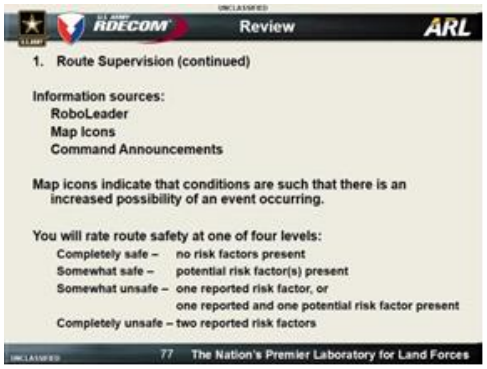
UNCLASSIFIED
RDECOM
Review
ARL
1. Route Supervision (continued)
Information sources:
RoboLeader
Map Icons
Command Announcements
Map icons indicate that conditions are such that there is an increased possibility of an event occurring.
You will rate route safety at one of four levels:
Completely safe – no risk factors present
Somewhat safe – potential risk factor(s) present
Somewhat unsafe – one reported risk factor, or
one reported and one potential risk factor present
Completely unsafe – two reported risk factors
UNCLASSIFIED
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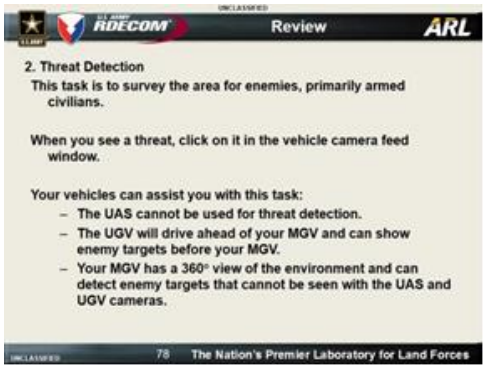
UNCLASSIFIED
RDECOM
Review
ARL
2. Threat Detection
This task is to survey the area for enemies, primarily armed civilians.
When you see a threat, click on it in the vehicle camera feed window.
Your vehicles can assist you with this task:
– The UAS cannot be used for threat detection.
– The UGV will drive ahead of your MGV and can show enemy targets before your MGV.
– Your MGV has a 360° view of the environment and can detect enemy targets that cannot be seen with the UAS and UGV cameras.
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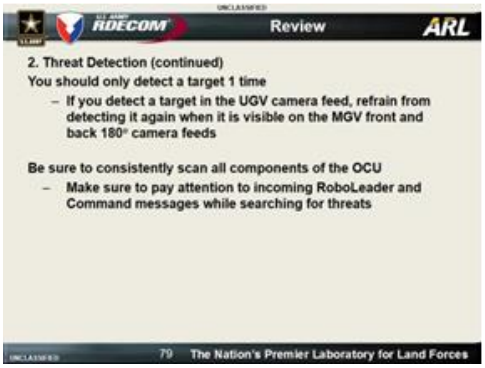
UNCLASSIFIED
RDECOM
Review
ARL
2. Threat Detection (continued)
You should only detect a target 1 time
– If you detect a target in the UGV camera feed, refrain from detecting it again when it is visible on the MGV front and back 180° camera feeds
Be sure to consistently scan all components of the OCU
– Make sure to pay attention to incoming RoboLeader and Command messages while searching for threats
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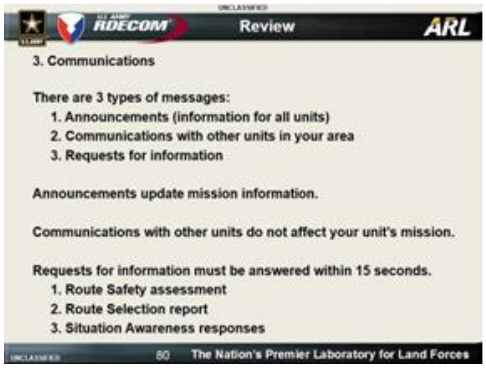
UNCLASSIFIED
RDECOM
Review
ARL
3. Communications
There are 3 types of messages:
1. Announcements (information for all units)
2. Communications with other units in your area
3. Requests for information
Announcements update mission information.
Communications with other units do not affect your unit's mission.
Requests for information must be answered within 15 seconds.
1. Route Safety assessment
2. Route Selection report
3. Situation Awareness responses
UNCLASSIFIED
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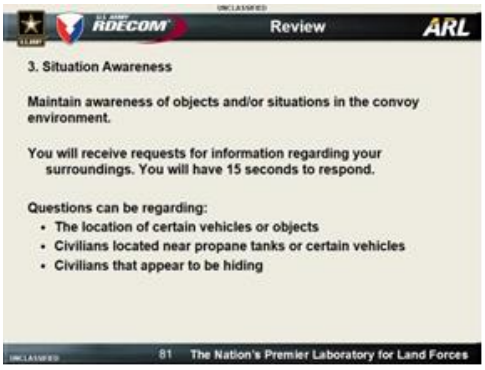
UNCLASSIFIED
RDECOM
Review
ARL
3. Situation Awareness
Maintain awareness of objects and/or situations in the convoy environment.
You will receive requests for information regarding your surroundings. You will have 15 seconds to respond.
Questions can be regarding:
• The location of certain vehicles or objects
• Civilians located near propane tanks or certain vehicles
• Civilians that appear to be hiding
UNCLASSIFIED
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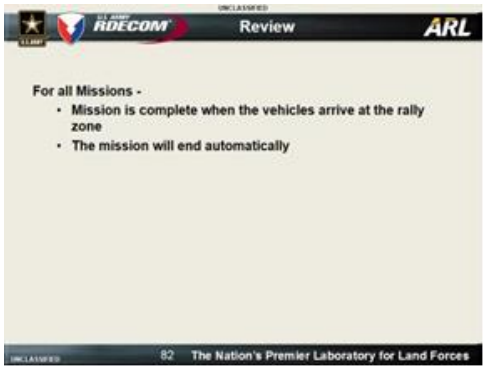
UNCLASSIFIED
RDECOM
Review
ARL
For all Missions -
• Mission is complete when the vehicles arrive at the rally zone
• The mission will end automatically
UNCLASSIFIED
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UNCLASSIFIED
RDECOM
STOP HERE
ARL
STOP
STOP
Please inform your experimenter that you have completed this part of the training.
At this point, you will perform one full practice scenario with all of the task components
• Route Supervision
• Threat Detection
• Communications
• Situation Awareness
When you have completed this practice mission, you have a short break, and then will begin your first mission
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Appendix K. RoboLeader Messages

Fig. K-1 RoboLeader message for agent reasoning transparency (ART) Level 1

Fig. K-2 Typical RoboLeader message, ART Level 2

Fig. K-3 Typical RoboLeader message, ART Level 3

Appendix L. Situation Awareness (SA) Questions

This appendix appears in its original form, without editorial change.

Level 1- What is happening?

SA1 Queries gauge how well the participant is monitoring and perceiving information about the experimental environment.

Mission 1

1. How many Dump trucks have you passed?
   Answer: B. 2

   A. 1
   B. 2
   C. 3
   D. 4
   E. None

2. What vehicle was positioned between the two walls?
   Answer: E. Tank

   A. Personnel Carrier
   B. Pickup Truck
   C. Fuel Truck
   D. Dump Truck
   E. Tank

3. What vehicle/object of interest did you just pass?
   Answer: B. Garbage Truck

   A. Personnel Carrier
   B. Garbage Truck
   C. Fuel Truck
   D. Dump Truck
   E. Propane Tank

4. You have just passed a person standing behind the wall. Identify them.
   Answer: A. Male Civilian

   A. Male Civilian
   B. Female Civilian
   C. US Military
   D. Armed Civilian
   E. None

5. Who was standing next to the Dump truck you just passed?
   Answer: D. 1 Male & 1 Female Civilian

   A. 1 Male Civilian
   B. 1 Female Civilian
   C. 2 Male Civilians
   D. 1 Male & 1 Female Civilian
   E. None

6. What object/vehicle of interest was next to the Garbage Truck you just passed?
   Answer: C. 2 Male Civilians

A. Personnel Carrier
B. Garbage Truck
C. Fuel Truck
D. Dump Truck
E. Propane Tank

Mission 2

1. Who was standing next to the Dump truck you just passed?
   Answer: C. 2 Male Civilians

   A. 1 Male Civilian
   B. 1 Female Civilian
   C. 2 Male Civilians
   D. 1 Male & 1 Female Civilian
   E. None

2. How many U.S. Military were standing by the Garbage truck?
   Answer: C. 3

   A. 1
   B. 2
   C. 3
   D. 4
   E. None

3. What vehicle/object of interest did you just pass?
   Answer: C. Fuel Truck

   A. Personnel Carrier
   B. Garbage Truck
   C. Fuel Truck
   D. Dump Truck
   E. Propane Tank

4. How many destroyed vehicles were near the Dump truck?
   Answer: A. 1

   A. 1
   B. 2
   C. 3
   D. 4
   E. None

5. What vehicle/object of interest was near the Propane Tank that you just passed?
   Answer: C. Fuel Truck

   A. Personnel Carrier
   B. Garbage Truck
   C. Fuel Truck
   D. Dump Truck
   E. Propane Tank

6. What was behind the wall that you just passed?
   Answer: B. Propane Tank

   A. Pickup Truck
   B. Propane Tank
   C. Fuel Truck
   D. Tank
   E. Dump Truck

Mission 3

1. How many Propane Tanks have you passed?
   Answer: B. 2

   A. 1
   B. 2
   C. 3
   D. 4
   E. None

2. Who was standing next to the Dump truck you just passed?
   Answer: D. 3 Male Civilians

   A. 1 Male Civilian
   B. 1 Female Civilian
   C. 2 Male Civilians
   D. 3 Male Civilians
   E. None

3. Since your last route selection, how many Dump Trucks has you passed?
   Answer: B. 2

   A. 1
   B. 2
   C. 3
   D. 4
   E. None

4. How many U.S. Military were standing by the Personnel Carrier?
   Answer: D. 4

   A. 1
   B. 2
   C. 3
   D. 4
   E. None

5. What was behind the wall that you just passed?
   Answer: D. Dump Truck

   A. Personnel Carrier
   B. Garbage Truck
   C. Fuel Truck
   D. Dump Truck
   E. Propane Tank

6. Who was standing next to the Personnel Carrier you just passed?
   Answer: C. 2 Male Civilians

   A. 1 Male Civilian
   B. 1 Female Civilian
   C. 2 Male Civilians
   D. 2 Female Civilians
   E. None

Level 2 –Why is it happening?

SA2 Queries evaluate how well the participant is integrating information from multiple sources in their decision-making. The event presented on the map will always be an answer choice, as well as three of the four potential events. The last answer choice will always be "Route Clear." These questions will appear shortly after the participant has answered the SA3 query, regardless of route selection. Each mission will contain 6 SA2 queries

Bravo unit - Why are you on your current route? (Select all that apply)

A. Avoid Potential IED
B. Avoid Comm Dead Zone
C. Avoid Dense Fog
D Avoid Gunfire/Sniper
E. Route Clear

Level 3-What will happen?

SA3 Queries evaluate how well the participant can predict the consequences of their chosen action. This question will be asked immediately after passing every decision point, regardless of route selection. There are 6 SA3 queries in each mission.

Bravo unit -

Please evaluate how safe your current route will be.

A – Completely Safe
B – Somewhat Safe
C – Somewhat Unsafe
D – Completely Unsafe

List of Symbols, Abbreviations, and Acronyms

ANOVA	analysis of variance
ARL	US Army Research Laboratory
ART	Agent Reasoning Transparency
CI	Confidence Interval
CP	Complacency Potential
CPRS	Complacency Potential Rating Scale
DT	Decision Time
ET	elapsed time
EXP1	Experiment 1
EXP2	Experiment 2
FA	false alarm
FC	Fixation Count
FD	Fixation Duration
Frust	frustration level
ID	individual difference
IED	improvised explosive device
IR	infrared
LOA	level of autonomy
MD	mental demand
Mdn	Median
MGV	manned ground vehicle
MIX	Mixed Initiative Experimental
N	Number
NASA-TLX	National Aeronautics and Space Administration-Task Load Index
OCU	operator control unit

OOTL	out of the loop
PAC	perceived attentional control
PDia	pupil diameter
Perf	performance
PhyD	physical demand
RED	Remote Eyetracking Device
RL	Roboleader
RSPAN	Reading Span Task
SA	situation awareness
SAT	Situation-awareness based Agent Transparency
SD	Standard Deviation
SE	Standard Error of the mean
SDT	Signal Detection Theory
SMI	Sensomotoric Instrument
SO	spatial orientation
SOT	Spatial Orientation Test
SpA	spatial ability
SV	spatial visualization
TD	temporal demand
TOR	Time of Report
UAV	unmanned aerial vehicle
UCF	University of Central Florida
UGV	unmanned ground vehicle
WMC	working memory capacity
d'	sensitivity
β	selection bias

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